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SURGERY

A Monthly Journal Devoted to the Art and Science of Surgery

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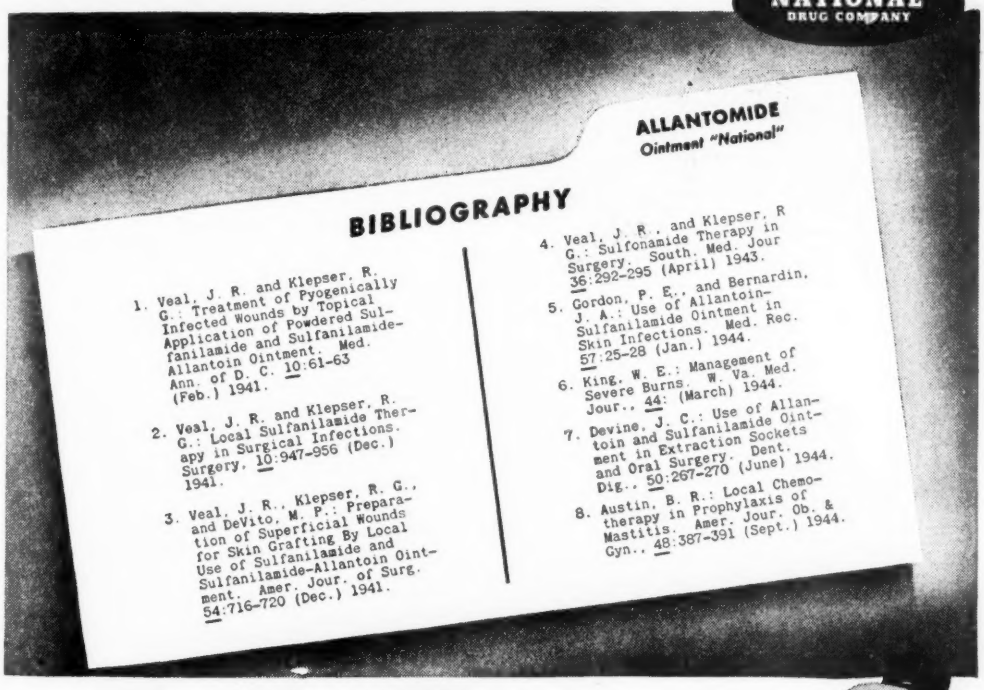
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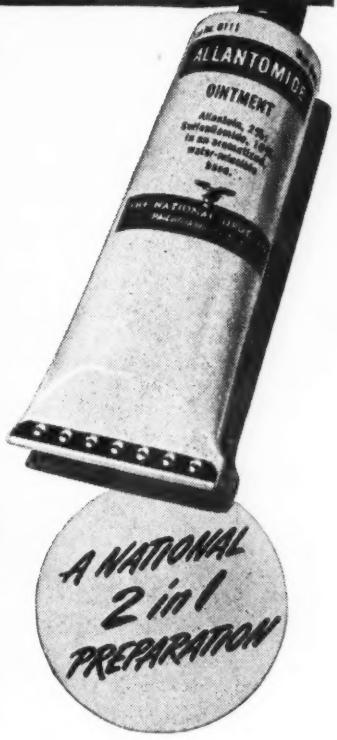

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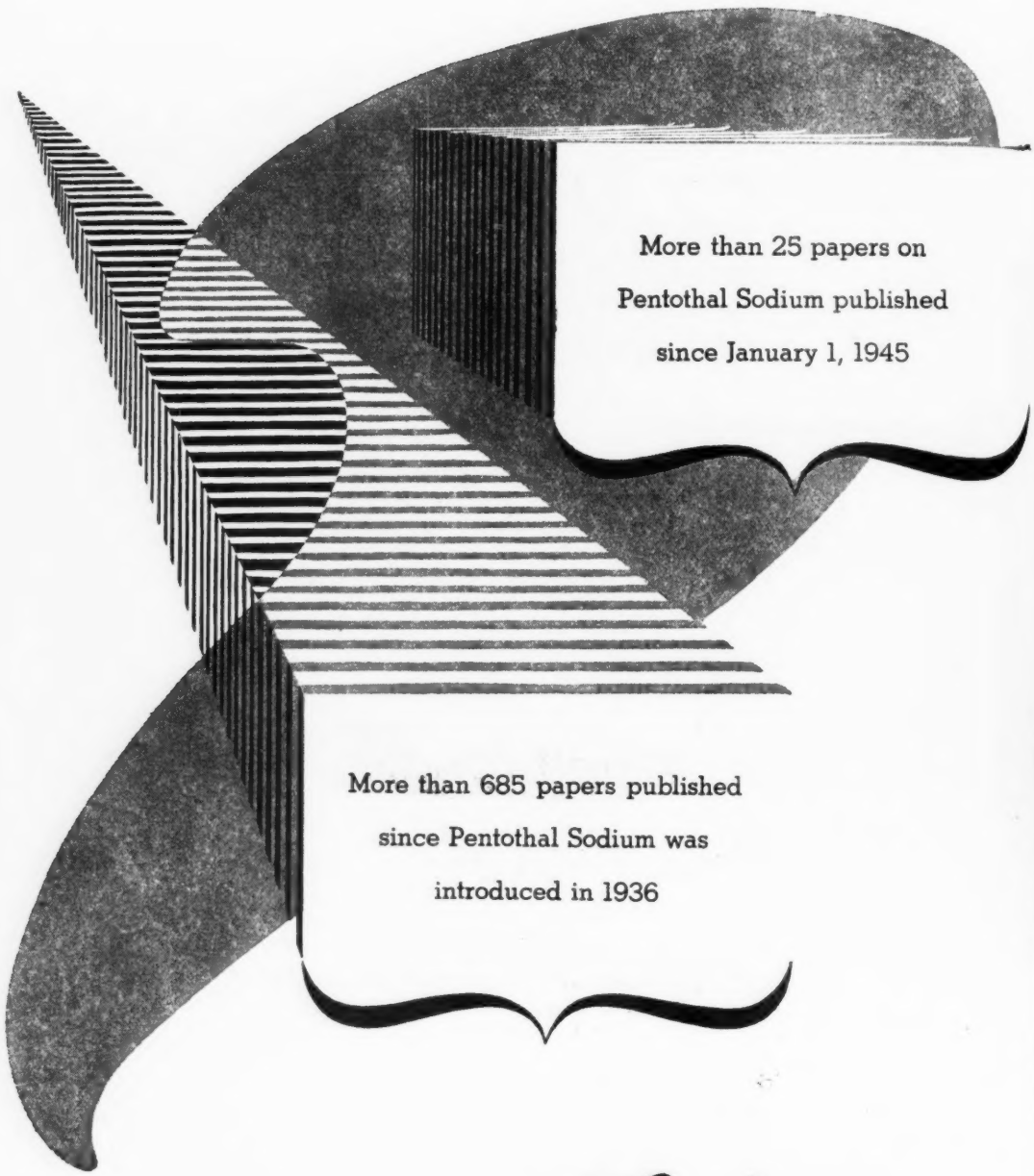
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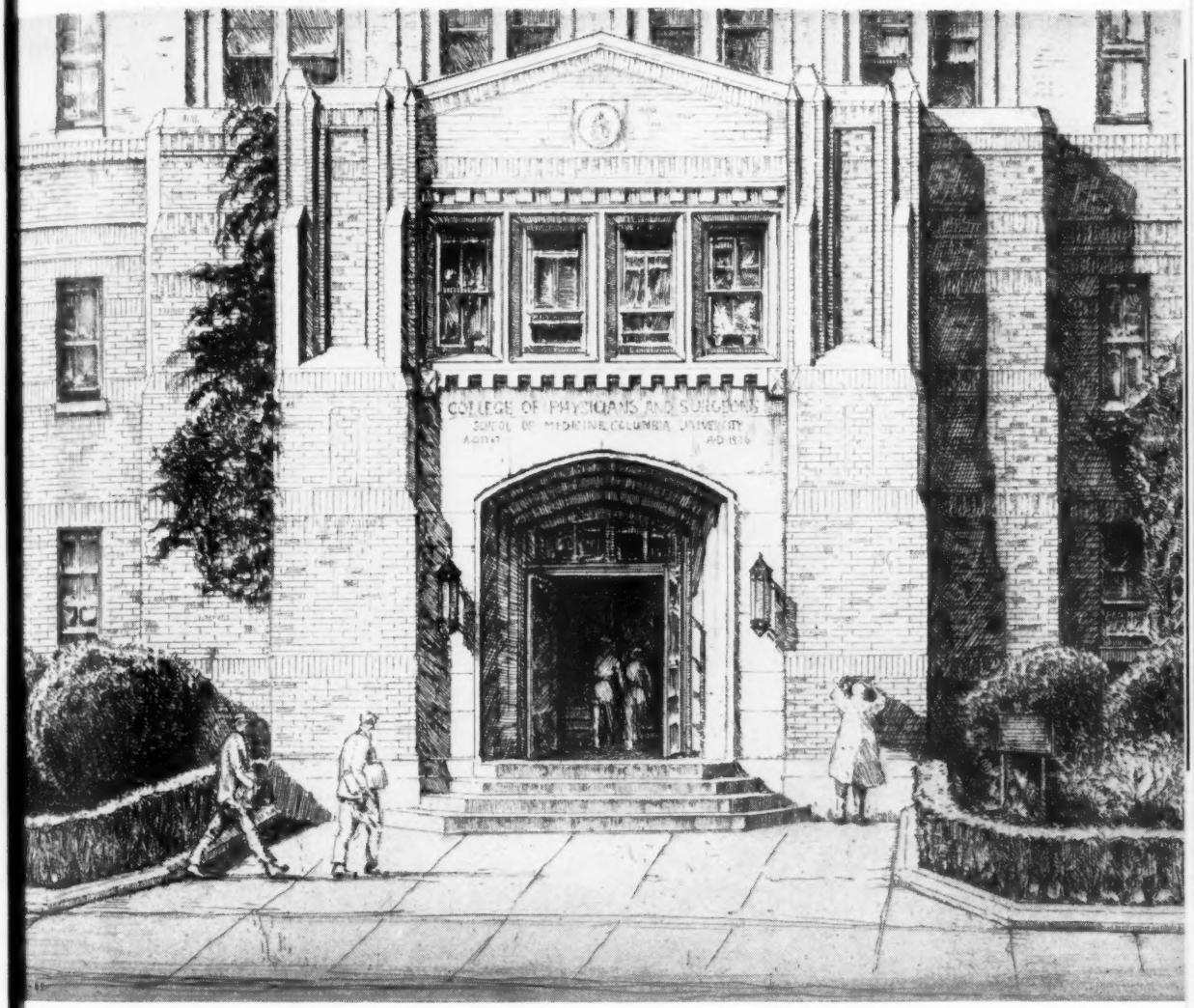

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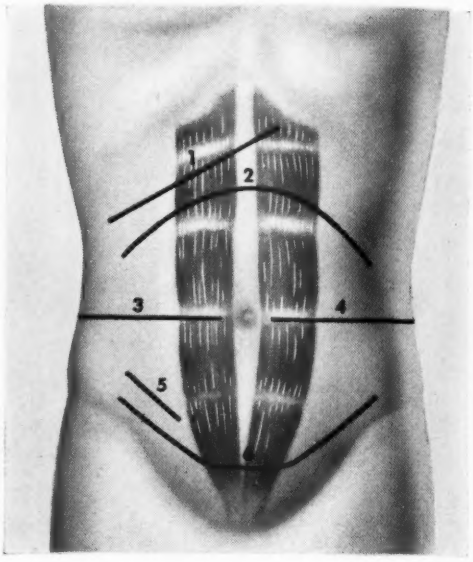
In suturing transverse incisions, no attempt is made to suture muscle—only the surrounding sheath. Approximation of the muscle edges is further aided by keeping the patient in a semi-reclining position with knees partially flexed.



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3. Resection of ascending colon, cecum, right sided lesions.
4. Descending colon, spleen and left sided lesions.
5. Appendectomy.

*6. Pelvic surgery, resection of sigmoid.

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The transverse incision across the lower abdomen provides a wide exposure of the pelvic organs, the rectum, the sigmoid and other pelvic structures. Resections and anastomoses can be performed through it which are not possible through the longitudinal incision.

The construction of this incision takes advantage of certain anatomical configurations. These are (1) the thinning and narrowing of the lower ends of the rectus muscle, (2) the termination of the posterior rectus sheath on a level just below the anterior superior spines and (3) the prolongation of the apex of the urinary bladder above this level toward the umbilicus.

MAKING THE INCISION

The skin incision is made completely across the lower abdomen starting from the anterior superior spine on one side, and curving downward, following the crest of the pelvis at a distance of two fingers' breadth, ending at the other anterior superior spine. It is usually made in a flexion crease. The subcutaneous fat and the anterior rectus sheath are incised in the same direction exposing the recti. The muscles are divided close to the symphasis pubis—i.e. through their tendinous portion, leaving stumps only long enough for resuturing. The severed muscles are retracted upwards until the incision in the posterior sheath can be made about one-half inch above the lower edge of this structure or almost directly between the anterior superior spine. When the peritoneum is incised a long prolongation of the bladder

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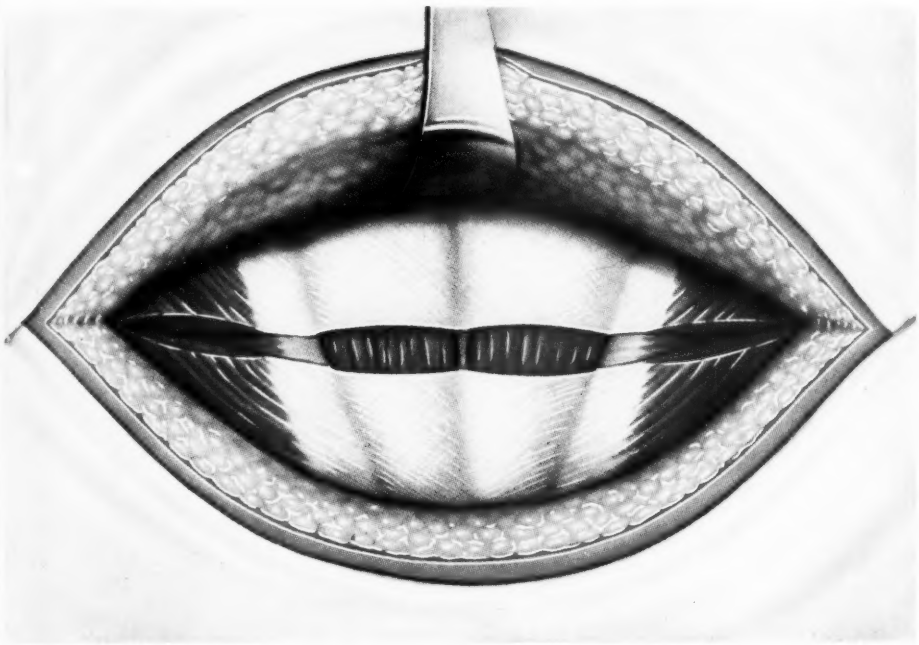
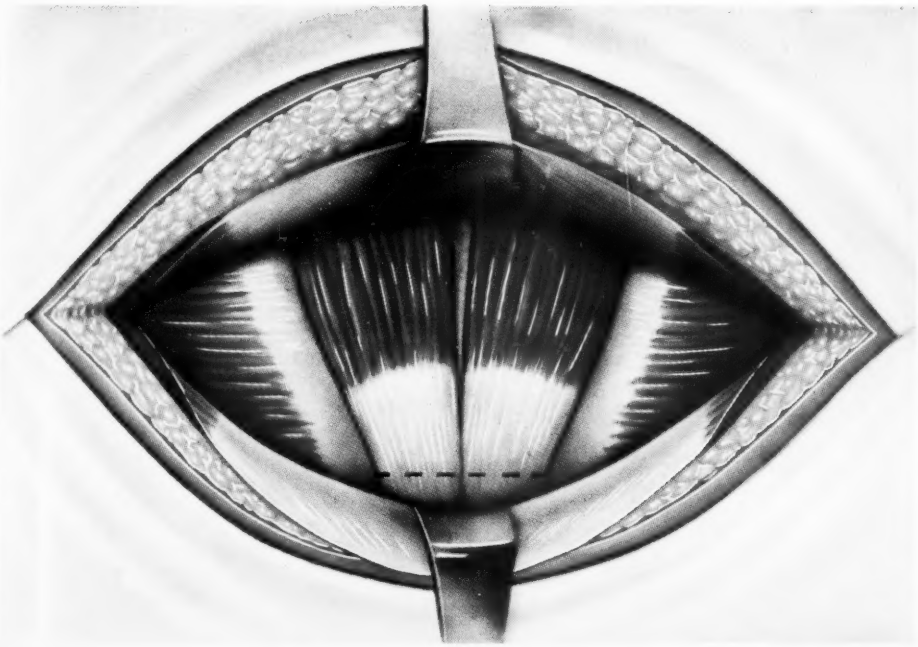


Exposure of external oblique muscles and fasciae.

apex must be watched for. The inferior epigastric arteries are clamped and ligated on either side of the rectus muscle when the posterior sheath is incised.

CLOSING THE INCISION

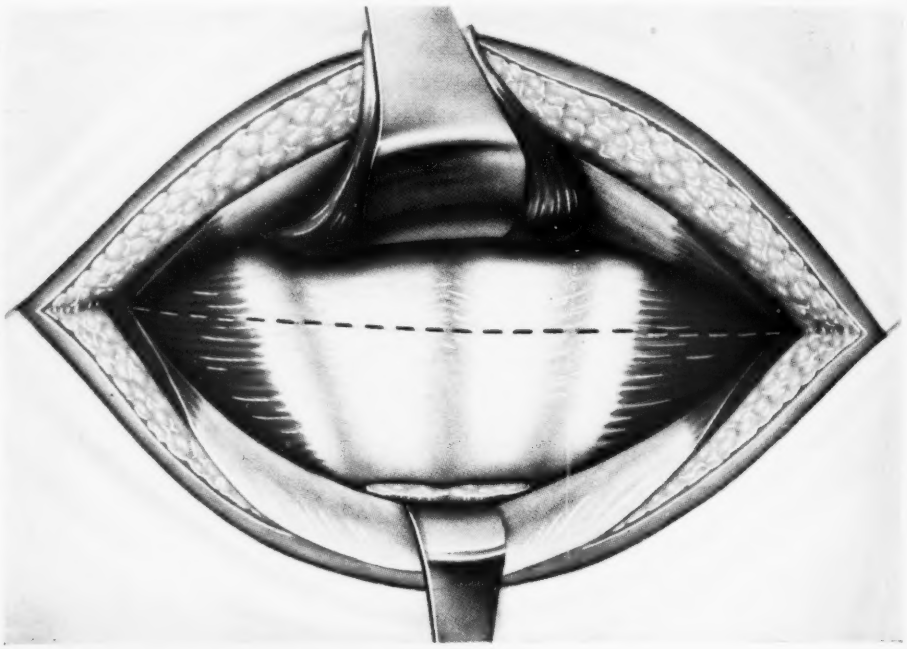
In closing the incision, the posterior sheath is closed with interrupted sutures. The muscles are laid down over this suture line and each is sutured to its stump by two interrupted



External oblique fascia has been cut transversely and retracted (exposing recti). Incision in recti indicated by dotted line.

Incisions that Minimize Wound Disruption

(Continued from Preceding Page)

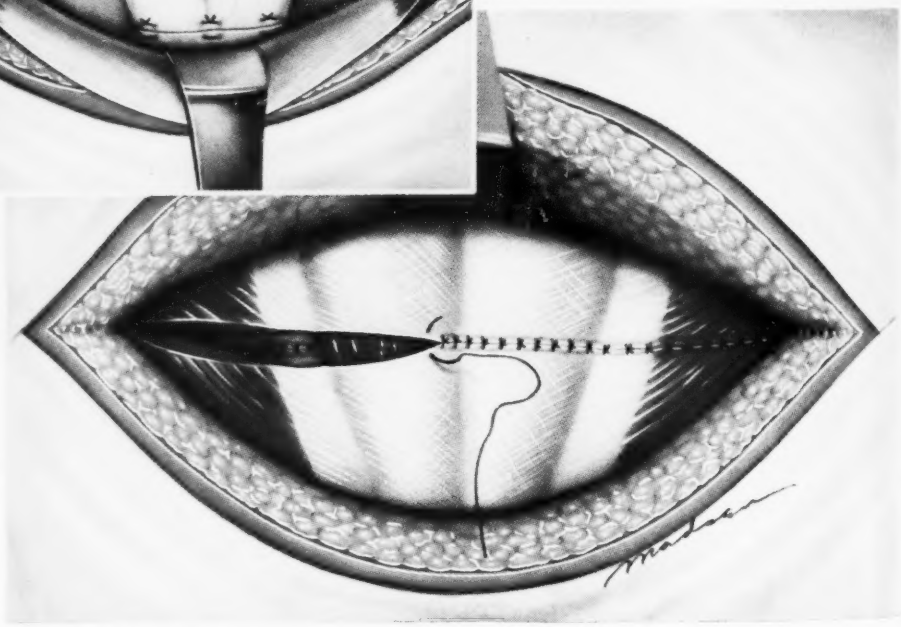


Recti have been cut in fibrous portion and retracted cephalad. Incision in posterior rectus sheath indicated by dotted line

mattress sutures. The anterior sheath is closed with interrupted sutures and the skin with interrupted skin sutures.

(Above) Suture of posterior sheath completed. Recti sutured.

(Right) Closure of anterior rectus sheath.



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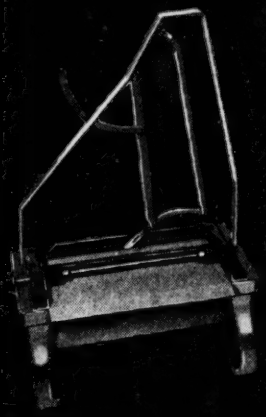

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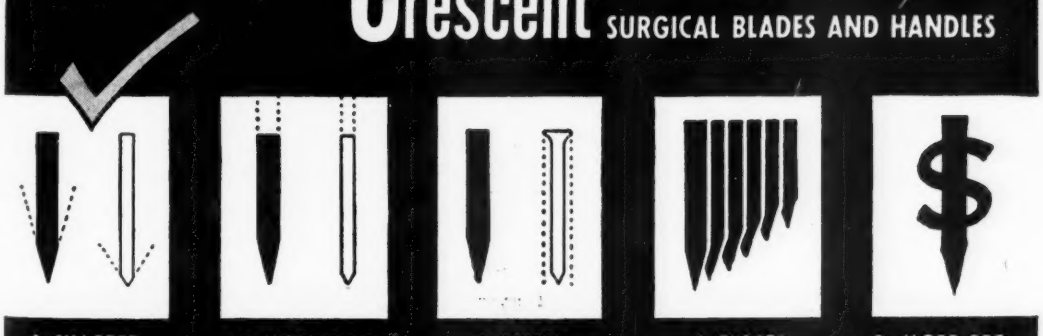

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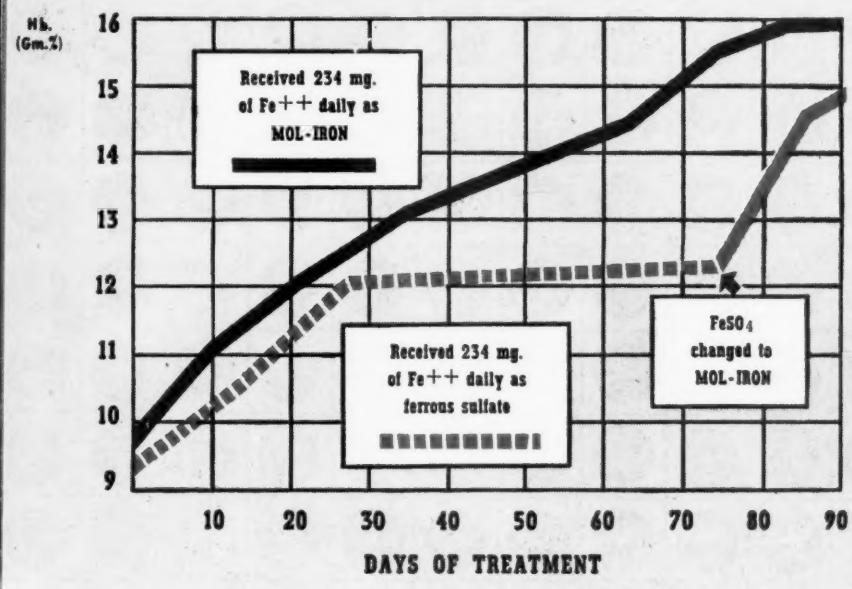

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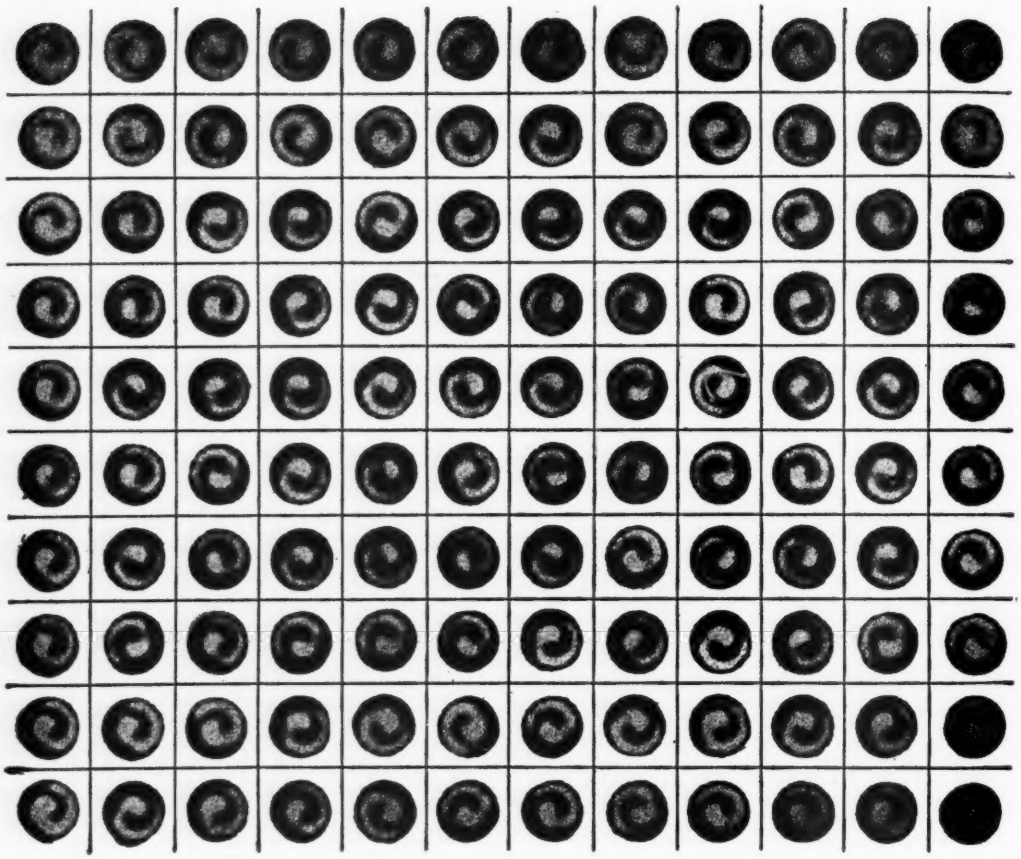

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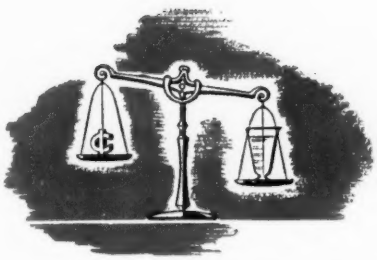

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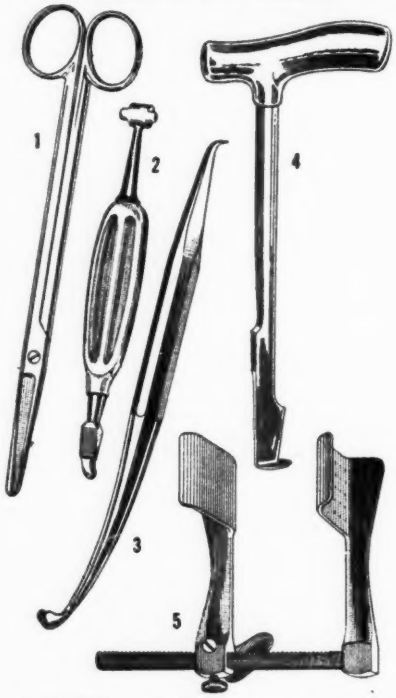

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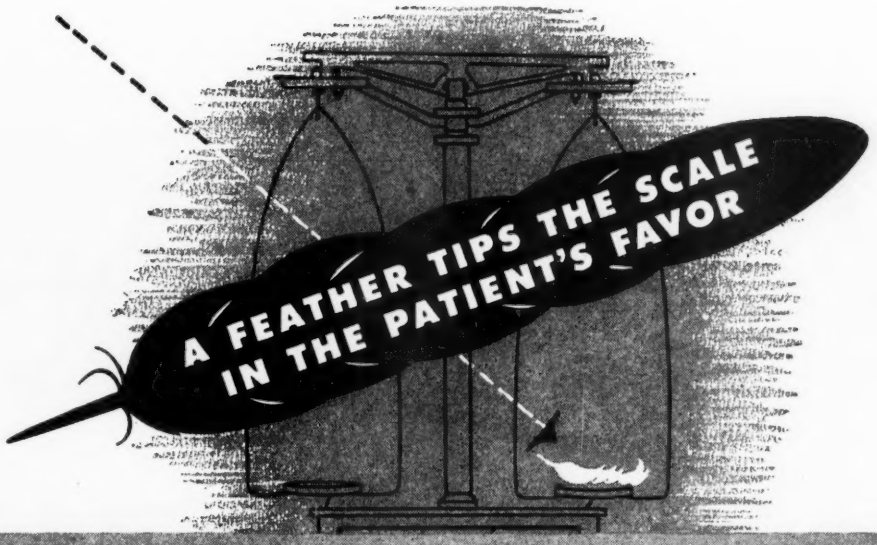

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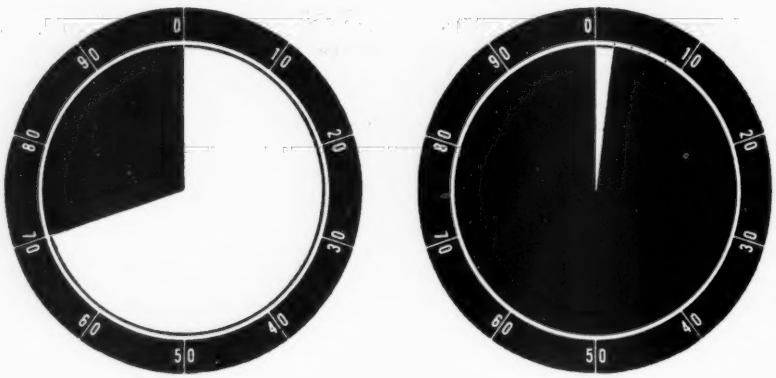

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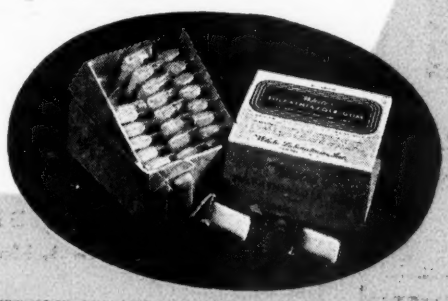

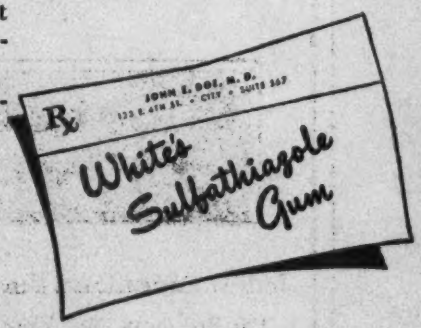

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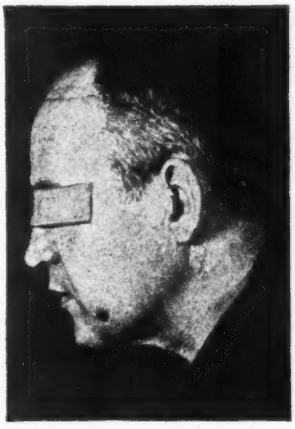

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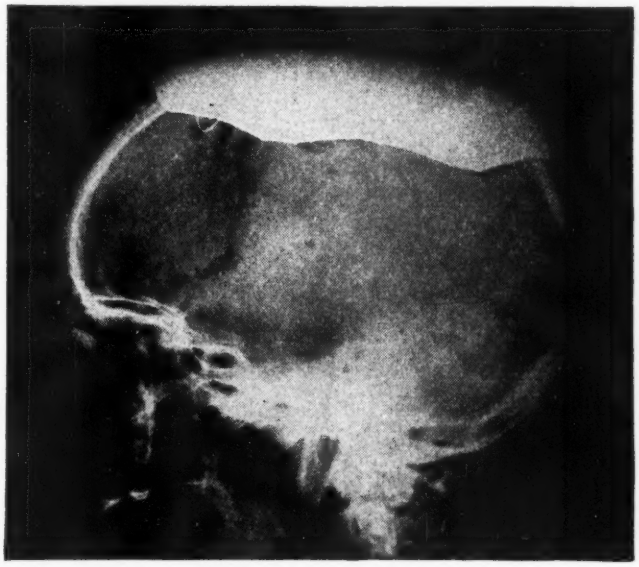

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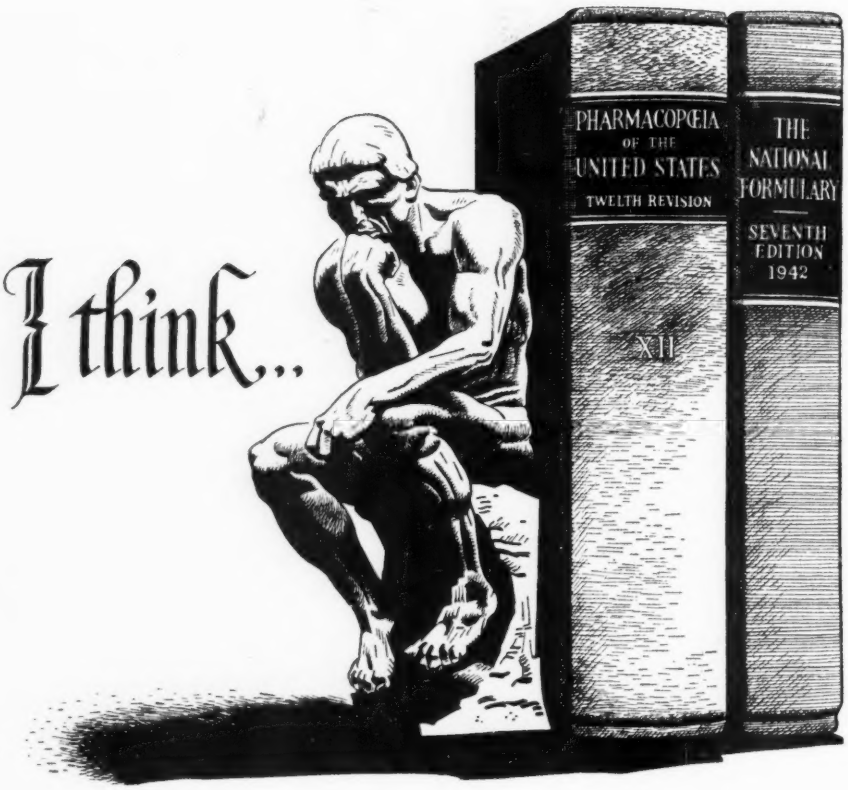

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SURGERY

VOL. 18 NOVEMBER, 1945 NO. 5

Original Communications

AN EXPERIMENTAL EVALUATION OF SULFASUXIDINE AND SULFATHALIDINE IN SURGERY OF THE COLON

EDGAR J. POTH, M.D., PH.D., AND CHARLES A. ROSS, M.A., GALVESTON, TEXAS, AND LIEUTENANT E. BRAVO FERNANDEZ, MEDICAL CORPS, ARMY OF THE UNITED STATES

(The Surgical Research Laboratory, University of Texas Medical Branch)

SUCCINYLSULFATHIAZOLE (Sulfasuxidine) was introduced as an intestinal antiseptic by Poth and Knotts[1, 2] in 1941, and phthalylsulfathiazole (Sulfathalidine) was similarily introduced in 1943 by Poth and Ross.[3, 4] These drugs were shown to be poorly absorbed from the gastrointestinal tract and to possess antibacterial activity sufficient to alter the bacterial flora affecting both the aerobic and anaerobic organisms. The clinical usefulness of these poorly absorbed sulfonamides as adjuvants in surgery of the colon has been demonstrated repeatedly as reviewed by Poth.[5, 6]

The oral administration of phthalylsulfathiazole (sulfathalidine) and succinylsulfathiazole (sulfasuxidine) was shown originally by Poth and Knotts,[1, 2] Poth,[7] Poth, Knotts, Lee, and Inui,[8] Zintel, Lockwood, and Snyder,[9] and Poth and Ross[10] to alter significantly both the aerobic and anaerobic bacterial flora of the gastrointestinal tract. The toxicity of these drugs is relatively low,[6] however, as occasionally occurs with all sulfonamides, any particular patient may be sensitive to the drug, requiring that all sulfonamides must be administered with caution.

The effect of the alteration of the bacterial flora by the oral administration of these two drugs to dogs on the results of crushing trauma and of enteroenterostomy involving the descending colon was studied by the following experimental procedure.

PROCEDURE

Mongrel dogs were placed in individual cages and fed boiled horse meat six times daily at four-hour intervals[11] for three days before operation. The quantity of meat fed was such that the animals were always sufficiently hungry to consume all of their food immediately. When a drug was administered, it was mixed with the meat.

Fecal specimens were taken directly from the rectum by aspiration into a sterile glass tube the day prior to operation and were cultured for coliform organisms on desoxycholate media as poured plates. The counts were made after incubation at 37° C. for forty-eight hours. Ordinarily, only the number

Aided by a research grant from Sharp & Dohme Inc., Philadelphia, Pa.
Received for publication, June 25, 1945.

of coliform organisms present was determined, and the alteration in these counts was taken to indicate the degree of alteration of the bacterial flora.

All operations were performed under ether anesthesia with observance of the usual surgical precautions. Immediately after operation, the animal was placed upon preoperative rations, which were available as soon as he cared to eat.

Crushing Injury of Ileum and Descending Colon.—Six animals were separated into three groups of (1) three control animals on standard meat diet, (2) one animal treated with 1.0 Gm. of succinylsulfathiazole per kilogram of body weight added to standard meat diet, and (3) two animals treated with 0.25 Gm. of phthalylsulfathiazole per kilogram of body weight added to standard meat diet.

In each instance a large Payr clamp, having a jaw 1.0 cm. in width, was applied across the bowel at the mid-section of the descending colon and across the ileum at a level 10 cm. proximal to the termination of the small antimesenteric artery extending cephalad from the ileocecal region. This clamp was left in place for two minutes and crushed the viscus so that only the submucosa remained intact. These animals all survived and were sacrificed after five days. The omentum was adherent at all crushed areas. The adjacent omentum and mesentery were extensively swollen and edematous in the case of the control animals, while only minimal swelling and edema were present in the drug-treated animals. Upon stripping away the adherent omentum, multiple small abscesses were revealed in the controls, whereas there was no evidence of infection when the animal had received either of the drugs. The following specimens were taken in each instance: a segment of bowel, 2.5 cm. in length, which included the crushed area, was excised and a control portion of bowel of equal length was taken approximately 10 cm. cephalad to the first. These specimens were wiped clean, weighed, and dried to constant weight by lyophilization. The water content is given in Table I. Somewhat less edema occurred when either sulfasuxidine or sulfathalidine had been administered prior to the trauma.

Aseptic Enteroenterostomy of Descending Colon.—Six animals were divided into three groups of two each. The animals in one group were placed on the standard meat diet, those in the second group received 1.0 Gm. daily of succinylsulfathiazole per kilogram of body weight in the standard diet, and those in the third group received 0.25 Gm. daily of phthalylsulfathiazole per kilogram of body weight in the standard diet. After ten days an aseptic end-to-end anastomosis was performed using the Poth intestinal clamp.[12] A continuous inner row of 2-0 chromic catgut was placed in a manner to turn in a minimum of bowel, reinforced with a row of interrupted Cushing sutures of No. 3 twist silk. These animals all survived and were sacrificed after five days. The omen-

TABLE I. LOSS OF WATER ON LYOPHILIZATION OF SEGMENTS OF TRANSVERSE COLON AND ILEUM FIVE DAYS FOLLOWING CRUSHING TRAUMA IN TREATED AND UNTREATED ANIMALS

	WATER CONTENT IN PER CENT			
	TRANSVERSE COLON		ILEUM	
TREATMENT RECEIVED PRECEDING TRAUMA	CRUSHED SEGMENT	CONTROL SEGMENT	CRUSHED SEGMENT	CONTROL SEGMENT
Sulfasuxidine	78.09	75.45	75.74	78.49
Sulfathalidine	79.31	78.19	80 93	76.81
Sulfathalidine	79.27	78.68	78.45	77.92
No drug	79.16	77.09	78.48	78.52
No drug	79.51	77.46	79.45	76.03
No drug	79.75	77.58	78.94	77.46

tum was adherent at the site of suture and was considerably more swollen and edematous in the controls than in the animals in which therapy had been employed. Otherwise, there was no significant difference. No microscopic studies were done.

End-to-End Anastomosis of Descending Colon by an Open Technique.—Since examination of the gross specimens obtained following the aseptic technique showed little difference between treated and untreated animals, an open technique accompanied by considerable soiling was studied.

Seventeen animals were divided into three groups: the first group consisted of seven animals placed on the standard meat diet; a second group, five animals given 1.0 Gm. daily of succinylsulfathiazole per kilogram of body weight in the standard diet; and a third group, five animals given 0.25 Gm. daily of phthalylsulfathiazole per kilogram of body weight in the standard diet.

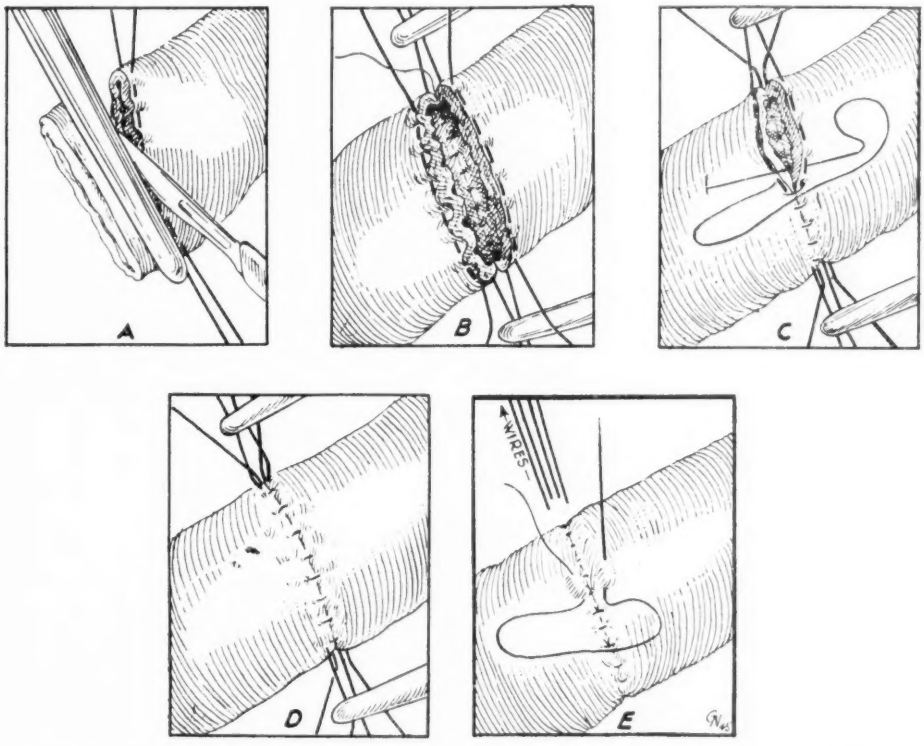

Fig. 1.—Open anastomosis of bowel. *A*, Fine stainless steel wires are inserted through the full thickness of the bowel wall to prevent retraction of the submucosa and muscularis, and eversion of the submucosa. By this method of fixation a more accurate and reproducible technique is realized. *B* and *C*, The inner continuous row of 000 chromic catgut is placed to include the fixation wires and invert the wall of the bowel. *D*, The fixation wires will be cut short on one end and withdrawn. *E*, The fixation wires are withdrawn, and the second row consisting of interrupted fine black silk sutures is introduced to complete the anastomosis.

In an attempt to find a satisfactory procedure for testing the value of the drugs in the preoperative preparation, an open technique giving a 50 per cent operative mortality was sought. The use of the technique illustrated in Fig. 1 resulted in the death of three out of seven of the control animals and in walled-off perforations at the suture line in the four animals which survived. When this same procedure was used on the animals in the second and third groups, which had been prepared with succinyl- and phthalylsulfathiazole, there were no deaths. No attempt was made to occlude the lumen of the bowel segments during suture, and extensive fecal contamination occurred regularly. All surviving animals were sacrificed after five days. The four control animals

which survived and were sacrificed on the fifth postoperative day showed massive, swollen, edematous omental adhesions surrounding gross perforations at the line of suture. The results obtained on the two series of drug-treated animals were practically identical. The suture lines were covered by adherent omentum which showed a minimum of swelling and edema. When the omentum was separated, two small stitch abscesses were revealed. There was no evidence of leakage in any instance.

Specimens were taken to include about 1.0 cm. of bowel on either side of the line of suture. A small section of the specimen was removed for microscopic study. The remainder of the specimen was dried to constant weight by lyophilization and the water content was compared to that of an adjoining segment of the bowel similarily treated (see Table II).

TABLE II. THE RESULTS OF OPEN ANASTOMOSIS OF THE DESCENDING COLON OF THE DOG FOLLOWING THE PROCEDURE ILLUSTRATED IN FIG. 1, IN TREATED AND UNTREATED ANIMALS

TREATMENT	PER CENT WATER IN SPECIMEN	PER CENT WATER IN CONTROL TISSUE	PER CENT WATER DIFFERENCE	CONDITION OF ANASTOMOSIS
Sulfasuxidine	75.85	75.00	+0.85	Intact, stitch abscess
Sulfasuxidine	79.71	79.30	+0.41	Intact, slight edema
Sulfasuxidine	76.69	76.12	+0.57	Intact, slight edema
Sulfasuxidine	72.03	76.22	−4.19	Intact, slight edema
Sulfasuxidine	75.10	76.29	−1.19	Intact, slight edema
Sulfathalidine	73.00	74.17	−1.17	Intact, slight edema
Sulfathalidine	75.30	74.60	+0.70	Intact, slight edema
Sulfathalidine	78.45	75.62	+2.83	Intact, stitch abscess
Sulfathalidine	76.27	78.40	+2.13	Intact, slight edema
Sulfathalidine	77.47	78.00	−0.53	Intact, slight edema
No drug	77.0	74.0	+3.0	Walled-off perforation
No drug	74.0	76.0	−2.0	Walled-off perforation
No drug	80.0	78.0	+2.0	Ruptured, *dead* 48 hr. P.O.
No drug				Ruptured, *dead* 48 hr. P.O.
No drug				Ruptured, *dead* 24 hr. P.O.
No drug	78.83	78.58	−0.25	Perforation, peritonitis
No drug	82.80			Walled-off perforation

The operations were performed in groups of three (one animal from each series) by the same operator (E. J. P.), on the same day, without his knowing specifically to which series any one animal belonged. The condition of the bowel and its contents, however, allowed the operator to differentiate immediately between the treated and untreated animals. Although it was not possible to prevent the surgeon from knowing whether or not the animal had received drug therapy preoperatively, every effort was made to perform identical operative procedures.

Microscopic study* of specimens taken through the line of suture revealed a considerable difference in the healing process between the control animals and those treated with either of the drugs. The specimens taken from the control animals showed an acute inflammatory reaction. There was little or no evidence of granulation tissue being formed. The serosal surface was covered with an exudate consisting of fibrin and polymorphonuclear leucocytes. There was marked hyperemia of all vessels with extensive edema.

The specimens taken from the animals which had received either sulfasuxidine or sulfathalidine showed a subacute inflammatory reaction. Along both edges of the suture line there was active proliferation of fibroblasts and newly formed capillaries. The surface was covered by a layer of pink-staining material made up of old fibrin, polymorphonuclear leucocytes in varying stages

*These studies were made by Dr. Paul Brindley, Professor of Pathology, University of Texas Medical Branch, Galveston, Texas.

of disintegration, and lymphocytes. The adjoining tissues were infiltrated with a moderate number of polymorphonuclear leucocytes, lymphocytes, plasma cells, and large mononuclear cells. The serosal layer was infiltrated with numerous lymphocytes, plasma cells, large mononuclear cells, and fibroblasts. Only a few polymorphonuclear cells were present in this layer. The tissue showed only a moderate amount of edema. In summary, the bowel of the control animals showed considerable edema, necrosis, and an acute inflammatory reaction with little or no evidence of healing, whereas the corresponding tissues from the drug-treated animals showed subsidence of inflammation with well-advanced healing and repair.

DISCUSSION

These controlled experiments show conclusively that both sulfasuxidine and sulfathalidine are valuable adjuvants in surgery upon the colon of the dog. The reaction, as revealed by the amount of edema of the omentum adherent to the line of suture, is significantly less when the the bacterial flora is modified by the administration of the drugs. The most clear-cut evidence of the value of these drugs is revealed by the results which followed the method of open anastomosis, wherein no effort was made to prevent fecal soiling of the operative field. Even though the degree of spillage was much greater following the administration of sulfasuxidine because of the semifluid nature of the contents of the bowel, there was a striking difference in the operative mortality and mormidity. Forty-three per cent of the control animals died of generalized peritonitis due to disruption of the line of suture. One hundred per cent of the control animals showed gross leakage at the line of suture. These observations are in contradistinction to absence of death and lack of gross leakage through the suture line when the animals had received sulfasuxidine and sulfathalidine. Furthermore, in the control experiments there was acute inflammation and little evidence of healing and repair by the fifth postoperative day. Following drug therapy, the inflammation had subsided and the tissues had undergone orderly repair and healing.

CONCLUSION

This study shows sulfasuxidine and sulfathalidine to be valuable adjuvants in surgery on the colon of the dog. The indications are that the so-called aseptic methods of anastomosis should be used whenever possible, but it is evident that an open technique may be undertaken with a considerably increased degree of safety. These observations support the satisfactory results obtained when man is treated in a similar manner.

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SURGERY OF THE COLON IN THE FORWARD BATTLE AREA

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WHENEVER colon wounds among battle casualties are mentioned, the subject is usually dismissed with the dictum, "Exteriorize all colon wounds." But, the question is often asked, "How?" Uncertainty may exist as to how to handle a particular colon wound. Should one always construct a double-barreled, spur colostomy? At the base hospitals some surgeons have felt that all colostomies should be closed by crushing a spur. Colon injuries, as a group, carry a high mortality and are among the most serious injuries that one encounters. However, the management of them and the indications for performing different types of colostomies seem clear cut; confusion over these points need not exist.

Trauma to the colon may be grouped as follows: (1) Perforations of the antemesenteric portion up to one-half of the diameter of the segment; (2) perforations of the mesenteric border and perforations of the antemesenteric border larger than one-half the diameter; (3) severely torn segments necessitating resection of a segment; (4) complete transections; (5) injuries to the mesentery producing nonviable segments; (6) the first five groups occurring in the rectosigmoid just above the pelvic floor; (7) The same five groups occurring in the rectum, between the pelvic peritoneum and the anus; (8) injuries necessitating right colectomy or cecectomy. This last group (8) will be discussed separately, as it involves the handling of ileal contents.

All exteriorizations of the colon, that is, all colostomies, should be planned and constructed, bearing in mind the simplest and most feasible method of closure at a later date. With this point in mind it becomes evident that a double-barreled spur colostomy need not always be performed, nor should one think that all colostomies should be closed by clamp-crushing of a spur. There are two types of colostomies to employ, each being indicated in specific cases. They are (1) the tangential or simple, no spur, loop colostomy and (2) the sutured, long, double-barreled, spur colostomy. Into Type 1 colostomy (the simple, no-spur loop type) falls Group 1 of the traumatic injuiries listed. Why? Because these antemesenteric perforations, less than one-half of the diameter of the gut in extent, are preferably and more simply closed, at a later date, by freeing the gut from the abdominal wall and simply closing the perforation with a continuous "0" chronic catgut suture in the fashion of Connell reinforcing this row with inter-

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rupted Lembert sutures of silk and dropping the segment beneath the fascia of the abdominal wall but exterior to the peritoneum. If the peritoneum is thin or cannot be dissected free from the fascia of the abdominal wall, then the sutured gut can be dropped back into the free peritoneal cavity with impunity. It is taken for granted that, when one elects to close a colostomy, he will undertake it only on a prepared colon; prepared mechanically with laxatives and irrigations with or without the use of succinyl-sulfathiazole, preferably by a combination of both. This type of colostomy is indicated also as a proximal colostomy in treating injuries in Group 6 which involve the rectosigmoid portion of the colon. The damaged portion of bowel at this level cannot be mobilized enough to be exteriorized. And, again, this simple, no-spur, loop colostomy is indicated in injuries of the rectum where a proximal colostomy is always necessary. Some think that a no-spur, loop colostomy does not sufficiently defunctionate the distal segment in order to employ it in Groups 6 and 7. After talking to base surgeons about this point and after seeing some of the patients with examples of insufficient defunctioning of the distal segment, I believe that, in part, this objection is based on faulty technique in performing the loop colostomy rather than on the principle of the use of this type of colostomy. One of the most frequently encountered complications of colostomies has been that of retraction. This retraction is due to improper mobilization of the segment. A fecal fistula results and, of course, insufficient defunctioning of the distal segment also results. In the majority of injuries falling in Groups 6 and 7, a properly performed no-spur, loop colostomy is quite sufficient. In exceptionally severe injuries of the rectum in which it is obvious that diversion of the fecal stream will be necessary for a long time, complete transection of the proximal colon with suturing of a long double-barreled spur colostomy to be crushed later with a clamp is preferable. A no-spur, loop colostomy brought out through a grid-iron incision with a small but adequate incision placed on the antemesenteric border of the exteriorized loop is a simple, quickly performed, and easily closed type of colostomy.

Conversely, trauma in Groups 2, 3, 4, and 5 should be treated by construction of a double-barreled spur colostomy. Thereby, the stage is set for early, easy closure by crushing the spur with a clamp. If these injuries are treated only by exteriorizing without constructing a long, double-barreled, spur colostomy, the re-establishment of continuity of the gastrointestinal tract at a later date will develop ino a complicated procedure.

The surgeon in the forward area should consider the problems confronting the surgeon in the base area when he constructs a colostomy, and have in mind, at the time, making the closure as simple as possible. The proper time to lay the groundwork for closing a colostomy is when that colostomy is first made. The surgeon in the forward area should indicate clearly on the record the type of colostomy he made and what type of closure he had in mind when making it. The surgeon in the base should heed this and perform a closure accordingly. It is simply a matter of cooperation between the two surgeons.

Trauma in Group 6 will, of course, need, as previously stated, a proximal no-spur, loop colostomy. In addition, since exteriorization of the perforation is anatomically impossible at this level, a simple antemesenteric perforation needs only to be closed. Large tears, etc., should be treated by resection. In this area a lateral anastomosis will usually be impossible, and an end-to-end

anastomosis will be the one of choice. This region, then, namely the rectosigmoid just above the pelvic peritoneum, is the only place that resection of the colon with anastomosis is advisable. To repeat for the sake of emphasis, if the area cannot be exteriorized a proximal colostomy is mandatory and the perforations should be closed or resected and anastomosed.

In regard to Group 7 (injuries of the rectum), a coccygectomy, through a horseshoe incision, is sometimes necessary for adequate exposure of the injured area for drainage. However, coccygectomy is not advised as a routine procedure because of the sequela of osteomyelitis of the sacrum which is sometimes encountered. In most instances adequate drainage has been obtained without coccygectomy. These lesions obviously should have in addition to posterior drainage a proximal colostomy. As just stated, in most instances one of the simple no-spur, loop type is sufficient. If feasible, closure of the perforation is desirable. If this breaks down nothing is lost. If one be confronted with a large torn segment it would not be wise to attempt an end-to-end anastomosis at the time of the initial operation. One should wait until a later date at the base to attempt re-establishment of the continuity of the gastrointestinal tract. At this elective time at the base, all of the available length of intestine can be utilized and one will have a better chance for primary healing. Also, to secure enough length of bowel in this limited fixed area to perform an anastomosis if, for instance, a segment of any length be lost, it would be necessary to incise the pelvic peritoneum, pull down sufficient redundant rectosigmoid for anastomosis with the shorter fixed portion near the anus, and to close the pelvic peritoneum around the displaced rectosigmoid at a level higher than that at which it was originally attached. Regarding the initial surgery, in cases of extensive damage to the rectum, a point to remember in performing the proximal colostomy in the redundant rectosigmoid is to leave sufficient length distal to the colostomy for a later pull-down operation from below as described.

"When should one open a colostomy?" One need have no fear of peritonitis developing from retrograde soiling through the opening in the abdominal wall. If a proximal colostomy is being constructed for an unexteriorizable injury to the rectosigmoid or to divert the fecal stream from a perforated rectum, the colostomy should be opened at the time at which it is made; that is, on the operating table. One is defeating the purpose of the operation if he waits twenty-four to forty-eight hours before opening the colostomy. During the period of delay the closed perforation or resection of the rectosigomid or the closed perforation or open laceration of the rectum will be bathed in feces. If a perforation in the mobilizable portions of the colon is exteriorized it should be left open; there is no need to place a clamp on it for twenty-four to forty-eight hours. If the exteriorized perforation is a very small one, one may wish to close it, leaving it exteriorized. If primary healing occurs, so much the better. If the suture line breaks down no harm is done. It is well to empty mechanically as soon after operation as possible all feces from the rectosigmoid or rectum.

In constructing a spur or loop colostomy the colon should be so mobilized that the colostomy lies free and quite loosely on the abdominal wall. All tension, tacking sutures to hold it to the abdominal wall, and dependence on clamps to prevent retraction into the peritoneal cavity, should be avoided. This is a most important point.

The length of a long, double-barreled, spur colostomy should be at least six inches, and the two long separate continuous rows of catgut sutures, about three-

fourth inch apart, should be placed on the antemesenteric borders of the two loops. These rows are best placed along two of the longitudinal fascial bands on the colon. Notes should be made of this so that when a clamp is placed for crushing the spur, it can be placed between these two rows of sutures. This will prevent any herniation of small bowel between the loops, any danger of clamping the mesentery, and will give an opening between the two loops that lies between two lines of sutures. A portion of these two lines of sutures will lie below the level of the peritoneum. For this reason, it is of the utmost importance to place the sutures not so deep as to run the risk of entering the lumen of the gut. If this precaution is not taken, there may be a late perforation due to infection along the suture line.

One point that should be emphasized in dealing with the colon is that of mobilization. The entire right colon, both flexures, and a portion of the rectosigmoid have about one-half of their diameter lying retroperitoneally. In explorations and in relief of tension on colostomies, the simple procedure of mobilizing these areas should be kept in mind. The lateral attachments of these portions of the colon are avascular, the mesentery coming in from the medial aspect, and they can be incised with impunity, displacing the colon medially.

Injuries of the right colon from the ileocecal junction distally, necessitating removal of the cecum and any portion of the right colon, are a problem because of the difficulty in dealing with the transected end of the terminal ileum. The open end of the ileum is, of course, a problem because of the erosive action of its contents if allowed to drain out into the abdominal wall. There are four ways of handling this problem. First, a primary anastomosis may be performed between the terminal ileum and the cut end of the transverse colon (end-to-side ileotransverse colostomy), the blind end of the colon being turned in by suture. Second, an end-to-side primary anastomosis may be performed, bringing out, through a stab wound, as a safety valve, the blind open end of the colon. Third, a lateral anastomosis may be performed between ileum and colon, bringing out both ends (ileum and colon) distal to the anastomosis as a double-barreled, spur colostomy. Fourth, ileum and colon may be exteriorized as a long, sutured, double-barreled ileocolostomy constructed for the purpose of early crushing of the spur with a clamp. The first three procedures are objectionable since they necessitate a primary anastomosis in an unprepared colon. This is too dangerous a procedure to employ. The fourth alternative is the one which has been used with good results. Early crushing of the spur back at the base hospital within two to three weeks, or earlier crushing at the front, preferably the former, will prevent any irreparable skin erosion. Postoperative care consisting of vitamins and correction of dietary deficiencies and restoration of blood chemistry to normal levels will play a large part in such treatment.

All exteriorizations should be brought out through separate stab wounds and not through the upper or lower poles of an exploratory incision. Often it has been convenient to bring a colostomy out through a débrided wound of entrance or exit, but this is avoided if possible.

There is a place for tube cecostomies in handling single perforations of the cecum. However, in general, it is preferable to exteriorize such wounds. The evacuation of the patient and the change of hands that he unavoidably falls into may produce periods of time when proper attention cannot be paid to the tube.

A tube may be of advantage in diverting the stream of ileal contents in an ileocolostomy, or may be used in a colostomy, but its period of usefulness is short as leakage occurs around the tube. In practice we have not employed tubes for such purposes.

Questionably viable areas of colon due to damaged mesentery or to trauma to the wall of the gut proper should be exteriorized.

The management of war wounds of the colon differs materially from the management of lesions of the colon generally encountered in civilian practice. The excellent results obtained in civilian practice by the performance of primary anastomosis on the properly prepared colon permitted the immediate replacement of the anastomosed portion into the general peritoneal cavity. In dealing with emergency war surgery it is felt that all colon injuries should be exteriorized and no primary anastomosis is warranted.

The opinions herein stated are based on two years' experience in performing initial, first priority surgery as the operating surgeon on a general surgical team of an auxiliary surgical group employed in several of the most forward hospitals set up next to a division clearing station. This experience was gained with the Seventh Army in the Sicilian Campaign and with the Fifth Army in the Italian Campaign.

CASE REPORTS

The following eight cases will illustrate the different types of colostomies and the conditions in which each was indicated.

Five cases of trauma to the right colon, including the cecum were of sufficient extent to require removal of cecum, ascending colon, and hepatic flexure. Each of these was handled by suturing a long, two row double-barreled, spur ileotransverse colostomy bringing the ileocolostomy out through a separate incision as described. Three of these patients (Cases 1, 2, and 3) died in the immediate postoperative course due to the severity of their wounds. This type of ileocolostomy, in itself, obviously did not contribute to death. One patient (Case 4) had an uncomplicated postoperative course. The ileostomy began functioning well on the third postoperative day. The patient was evacuated to a base section on the fifteenth postoperative day. On this day there was a small amount of redness beginning to appear around the ileostomy opening. Follow-up on this case revealed that the spur was satisfactorily crushed during the fourth week and that no serious errosion of the abdominal wall had occurred.

One patient (Case 5) was operated upon at a time recent to that of this writing, and follow-up data on the case have, as yet, not been obtained. Due to the rapidity with which our battle lines were moving forward at the time, it was necessary to leave this patient on the third day. Although obviously suffering from peritonitis, the patient seemed to be withstanding the infection and I assume that he survived.

Case 6 illustrates trauma to the splenic flexure of such extent that it was necessary to resect this portion of the colon and construct a long, sutured double-barreled, spur colostomy. This case also is exemplary of that group of injuries occurring in the rectosigmoid so low down that they cannot be exteriorized.

Cases 7 and 8 are examples of injuries of the colon that required only simple exteriorization of the perforation as a no-spur loop colostomy.

CASE 1.—A soldier was injured 2:00 A.M., Jan. 23, 1944, by shell fragment. He was operated upon at 6:00 P.M., Jan. 23, 1944. The patient was in extreme shock when admitted to the field hospital. Examination revealed a penetrating wound of the right upper quadrant

of the abdomen and a severe compound comminuted fracture of the right tibia and fibula, middle third. Exploratory laparotomy was carried out through an upper midline incision (xiphoid to just above the umbilicus). Macerated hepatic flexure, ascending colon, and terminal ileum were found. Shell fragments lay free in the pelvis. No other intra-abdominal viscera were injured; extensive fecal soiling. The entire right colon and a portion of the right half of the transverse colon were removed, along with the first four inches of the terminal ileum. Long-sutured, spur, ileotransverse colostomy was constructed and brought out through the débrided wound of entrance. The fracture was débrided and a cast applied. In spite of supportive therapy of whole blood, plasma, glucose, and saline before and during operation in the postoperative course, the patient died Jan. 25, 1944. Autopsy revealed only the facts found at operation.

CASE 2.—A soldier was injured 9:00 A.M., March 12, 1944, by shell fragment. He was operated upon at 6:00 P.M., March 12, 1944. The patient responded to treatment for shock when admitted to the field hospital. Examination revealed a penetrating wound just below the costal margin in the right posterior axillary line and a left thoraco-abdominal wound with the wound of entrance in the tenth interspace, left midaxillary line. X-ray showed a small amount of clouding at the base of the left lung field, with no pneumothorax. A foreign body lay in the left upper quadrant of the abdomen just below the diaphragm. A foreign body from the wound of entrance on the right lay in the right lumbar muscles. Urine was grossly bloody on catheterization, at admission. Exploratory laparotomy was carried out through an upper midline incision, xiphoid to umbilicus. Right nephrectomy was done for a severely mascerated kidney with large laceration through the pelvis of the kidney. Right colectomy was done for multiple perforations of the ascending colon and impairement of the blood supply to the cecum. A long, sutured, double-barreled, spur ileotransverse colostomy was constructed and brought out through a right McBurney incision. The foreign body was removed from the lumbar muscles. The foreign body in the left upper quadrant was removed from where it was found to be lying on the spleen without injuring that organ. Perforation of the left diaphragm was sutured from below. The penetrating wound on the left side of the chest was débrided. The left lung expanded under positive pressure and the wound was closed to prevent sucking. The patient died March 15. Autopsy revealed a purulent generalized peritonitis, paralytic ileus, and bilateral pneumonic consolidation of the lower lobes of both lungs.

CASE 3.—A soldier was injured 10:00 P.M., May 31, 1944, by shell fragment. He was operated upon at 3:30 A.M., June 1, 1944. Examination revealed a perforating wound of the abdomen, with its entrance in the upper midline just above the umbilicus, and exit in the right flank. He was in severe shock on admission to the field hospital but responded to shock therapy. Exploratory laparotomy was made through the upper midline incision. The right colon, hepatic flexure, and right half of the transverse colon were torn to shreds. There was a small perforation of the second portion of the duodenum and almost complete transection of the lower third of the stomach. Extensive muscle damage was present in both wounds. There was extensive peritoneal contamination from the colon and the stomach. The cecum, ascending colon, hepatic flexure, and right half of the transverse colon were removed. A long, sutured, double-barreled, spur ileotransverse colostomy was brought out through the left upper quadrant subcostal stab wound. Laceration of the stomach was sutured and perforation of the doudenum closed. The patient died forty-eight hours later. Autopsy revealed only the facts known at operation.

CASE 4.—A soldier injured 10:00 A.M., Feb. 19, 1944, was operated upon 8:00 P.M., Feb. 19, 1944. Examination revealed a penetrating wound of the abdomen, with the wound of entrance just below the right costal margin posterior to the axillary line. A missile (enemy rifle bullet, .30 caliber) could be felt beneath the skin in the back just to the right of the third lumbar vertebra. Exploratory laparotomy was made through the upper midline incision. The cecum and ascending colon, which were irreparably damaged; were removed. A long, sutured double-barreled, spur ileotransverse colostomy was brought out through a stab wound in the right upper quadrant of the abdomen. The foreign body was removed through a counter-incision posteriorly. The postoperative course was uncomplicated. The patient was evacuated to the base area on the fifteenth postoperative day; the spur was crushed in the fourth postoperative week. There was minimal erosion of the abdominal wall. The upper midline incision healed.

CASE 5.—A soldier was injured 2:00 A.M., June 1, 1944, by shell fragment and operated upon 7:00 P.M., June 1, 1944. Examination revealed a perforating wound of the abdomen. The wound of entrance was in the right flank and wound of exit in the midline below the umbilicus. The tract of the missile went through the crest of the right ilium causing extensive damage to the cecum and ascending colon and multiple perforations and laceration of the ileum. Urine was clear on catheterization. Hemorrhage was severe from mesenteric vessels. There was extensive peritoneal contamination from the colon and ileal contents. Exploratory laparotomy was made through an upper midline incision. Two resections of ileum were completed with end-to-end anastomoses. Two perforations of the ileum were closed, and the cecum and ascending colon removed. Long, sutured, double-barreled spur ileotransverse colostomy was brought out through a right subcostal stab wound. Wounds of entrance and exit were débrided. Circumstances necessitated leaving this patient on the third postoperative day. He was quite ill but seemed to be withstanding peritonitis at that time. Pulse was 100, with good volume; blood pressure, 120/70. At the present time there has been no follow-up.

CASE 6.—A soldier was injured 2:00 P.M., May 23, 1944, by small arms fire. Operation was done 12:30 A.M., May 24, 1944. (1) Perforating wound of the abdomen was found with the wound of entrance in the eleventh interspace, left, just below the diaphragm, posterior to the axillary line; the wound of exit was in the perineum just to the right of the anus. There was perforation of the lower pole of the left kidney; there were multiple perforations of the splenic flexure of the colon. Two antemesenteric border perforations of the rectosigmoid just above pelvic floor were found, as were multiple perforations of the midjejunum and two perforations of the ileum. There was a through-and-through wound of the bladder. (2) A perforating wound of the left lower leg resulted in compound comminuted fracture of the lower third of the fibula. (3) The right thigh had a perforating wound. (4) Perforating wounds of both feet were present, with multiple fractures. Exploratory laparotomy was made through an upper midline incision which was later extended around the umbilicus into a lower midline incision. Resection of the midjejunum was done with end-to-end anastomosis. The two perforations of the ileum were closed. Mobilization of the splenic flexure of the colon and removal of this portion of colon included all of the perforations. Construction of a long sutured, double-barreled, spur colostomy was brought out through a left subcostal stab. The left kidney was packed to control bleeding and the pack brought out through the débrided wound of entrance. Closure was made of the two perforations of the rectosigmoid and of the two of the bladder. Suprapubic cystostomy was done. The incision was closed rapidly with through-and-through silver wire. All other wounds were débrided.

Circumstances necessitated leaving this patient on the sixth postoperative day. At that time he had a fair chance to recover. He had responded well to vigorous intravenous therapy of blood, plasma, saline, and glucose before, during, and following operation. Temperature was 101° F., pulse 100, blood pressure 120/60. The nasal tube had been removed and the patient was taking fluids by mouth. Colostomy was functioning well and the abdomen was soft. Urine was clear and in large amounts. Later follow-up revealed that at end of two weeks the patient was progressing satisfactorily.

CASE 7.—A soldier injured 1:00 P.M., May 31, 1944, by shell fragment, was operated upon 12:00 P.M., May 31, 1944. A thoraco-abdominal wound was on the left side with a compound comminuted fracture of the tenth rib, midaxillary line. There was a one-inch laceration at the edge of the lower lobe of the left lung, a four-inch tear in the left diaphgram, and laceration of the spleen. A foreign body lay in the lumen of the splenic flexure of the colon. The left kidney was not damaged.

The tenth left rib was resected after aspiration of 1,000 c.c. of blood from the left pleural cavity. The left phrenic nerve was crushed and the tear in the diaphragm enlarged. Splenectomy and exploration were through the diaphragm. The foreign body was removed from the colon. The splenic flexure was mobilized and perforation exteriorized as a no-spur, loop colostomy through a left subcostal stab wound. Perforation of the colon was in the antemesenteric border. Intercostal nerves 7, 8, 9, 10, and 11 were injected with 5 c.c. of 1 per cent novocain. Sulfanilamide was used in the peritoneal and pleural cavities. The diaphragm was closed by imbricating with interrupted silk sutures. The pleural cavity was irrigated with saline solution. The lung expanded with positive pressure. The chest wall was closed in layers with interrupted sutures of cotton.

The patient was in good condition when last seen on the fourth postoperative day. At the present time there has been no follow-up.

CASE 8.—A soldier was injured 3:00 A.M., Jan. 30, 1944, by shell fragment. He was operated upon 2:00 P.M., Jan. 30, 1944. There was a perforating wound of the abdomen with entrance at the right costal margin below the diaphragm at the anterior axillary line and wound of exit at the left upper quadrant of the abdomen at the level of the umbilicus. There was a perforating wound of the left upper arm without fracture or injury to the nerves or vessels. Exploratory laparotomy was made through an upper midline incision. A large bleeding tear in the dome of the liver was packed and the pack was brought out through the débrided wound of entrance. The stomach was transected at the junction of the middle and lower thirds. Sleeve resection of the stomach was done with end-to-end anastomosis. Perforation of the mesenteric border of the midjejunum was resected with end-to-end anastomosis. The tear in the midtransverse colon on the antemesenteric border was exteriorized as a no-spur loop colostomy through the débrided wound of exit. The wound of the arm was débrided.

The patient was evaculated to the base area on the fourteenth postoperative day in good condition. The colostomy was functioning well and he was taking a soft diet. The liver pack was removed and one cigarette drain was placed in the tract to liver.

OPERATIVE RESULTS OF SURGERY OF THE COLON FOR NEOPLASTIC DISEASE

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DURING the seven-year period between Jan. 1, 1937, and Dec. 31, 1944, an increasing number of patients with neoplastic diseases of the colon have been operated upon at the State University of Iowa Hospitals. The records of the cases during this period were reviewed for evaluation of the results with the various operative procedures. This period represents a generally favorable background for comparative results because of the increasing adequacy of preoperative and postoperative care. It is rather universally agreed, as emphasized by Whipple,[10] that treatment of cancer and its adequate removal have been extended markedly in recent years. There is a better understanding of the importance and the means of maintaining fluid, electrolyte, and protein balance. The liberal use of whole blood before, during, and after the operation has been invaluable in improving the results.

Exploration was carried out in 224 patients for neoplasms of the colon. Of these, 117 had resection of the colon, a resectability rate of 52 per cent. All deaths occurring during the period of hospitalization in this group of patients are included in the mortality figures. There were 46 deaths in 224 patients operated upon, a mortality of 20.5 per cent. In 117 resections, 23 deaths occurred, a mortality of 19.6 per cent. There were 17 deaths in 81 patients in whom palliative operations were done for the relief of obstruction, a mortality rate of 20.9 per cent (Table I). Of the total, 142 lesions of the left side and 82 lesions of the right side were encountered.

NEOPLASMS OF RIGHT COLON

Of patients with neoplasms of the right side of the colon, 82 were explored, with resection in 49. Excluding the two resections for polyposis, this gives a resectability rate for malignancy of the right side of 58.8 per cent.

When operable, the usual procedure done was a one-stage resection with immediate ileocolostomy, either end-to-side or side-to-side. In this manner 41

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TABLE I. MORTALITY RATES

PROCEDURE	NO. OF CASES	NO. OF DEATHS	MORTALITY PER CENT
	Curative Resections		
Right side			
Right hemicolectomy	49	14	28.6
Left side			
End-to-end anastomosis	21	4	19.0
Anterior resection or Hartman	14	0	
Modified Mikulicz	33	5	15.1
Total	117	23	19.6
	Palliative Operations		
Right side malignancy	22	4	19.0
Left side malignancy	59	13	22.0
Total	81	17	20.9
	Simple Exploration		
Right and left exploratory laparotomy	26	6	23.1
Total	224	46	20.5

resections were carried out with 12 deaths, a mortality of 29.2 per cent. Four Mikulicz type procedures after the fashion of Lahey[4] were done with 2 deaths, a mortality of 50 per cent. A two-stage resection was done in 2 cases with no deaths. Two cases of hemicolectomy with ileostomy were recorded with no deaths (Table II).

TABLE II. RESECTIONS OF THE RIGHT COLON

OPERATIVE PROCEDURE	NO. OF CASES	NO. OF DEATHS	MORTALITY PER CENT
	Cancer		
One stage	41	12	29.2
Mikulicz	4	2	50.0
Two stage	2	0	
	Polyposis		
Colectomy with ileostomy	2	0	
Total	49	14	28.6

The causes of death are listed in Table III. Sepsis in the form of either localized or generalized peritonitis accounted for 57.13 per cent of all the deaths. Pneumonia, cardiac failure, mesenteric thrombosis, and urinary tract infection account for the remaining 6 deaths.

TABEL III. CAUSES OF DEATH IN RIGHT HEMICOLECTOMY

CONDITION	NO.	MORTALITY PER CENT OF TOTAL
Generalized peritonitis	6	42.9
Localized peritonitis	2	14.3
Bronchopneumonia	2	14.3
Cardiac failure	2	14.3
Mesenteric thrombosis	1	7.0
Urinary tract infection with septicemia	1	7.0
Total	14	100.0

NEOPLASMS OF THE LEFT ABDOMINAL COLON

Of 142 lesions of the left side of the colon which were explored, 68 were resected, an operability rate of 47.8 per cent. There were 9 deaths in these 68 resections, a mortality of 13.2 per cent.

Three types of procedures were used in the operative attack on lesions of the left side, in part dependent upon location. There were 33 modified Mikulicz procedures after the method of Rankin,[6] with 5 deaths, a mortality of 15.1 per cent; 21 resections with immediate anastomosis were done with 4 deaths, a mortality of 19 per cent, and 14 anterior resections or Hartman procedures (3) with no deaths (Table IV).

TABLE IV. RESECTIONS FOR LEFT SIDE OF COLON

OPERATIVE PROCEDURE	NO.	DEATHS	MORTALITY PER CENT
Modified Mikulicz	33	5	15.1
Resection and immediate end-to-end anastomosis	21	4	19.0
Hartman procedure	14	0	0.0
Total	68	9	13.2

The comparison of results of the modified Mikulicz procedure and the end-to-end anastomosis is of particular interest. Reports in the literature show a division of opinion among surgeons with respect to the type of procedure which should be used. Some favor resection with immediate anastomosis while others advocate the Mikulicz operation or one of its modifications. Among the advocates of the modified Mikulicz procedure are Rankin,[6] Cattell,[2] Jones,[3] and Mayo and Twyman.[5] Some of the proponents of resection and aseptic anastomosis are Stone and McLanahan,[8] Whipple,[10] Wangensteen,[9] Zinninger and Hoxworth,[11] and Allen.[1] If mortality and morbidity do not differ in the two procedures, resection of the bowel with immediate restitution of its continuity would seem the more desirable.

MODIFIED MIKULICZ RESECTION

There were 33 modified Mikulicz resections of the left side of the colon with 5 deaths, a mortality of 15.1 per cent (Table I). Of these resections, 32 were for carcinoma and 1 for sigmoiditis. The causes of death are listed in Table V.

Sepsis was responsible for all of the deaths in this group. Peritonitis was responsible for 60 per cent. A brief analysis of the deaths follows.

1. T. H. (No. 40-12891) had marked obstruction of the colon at the time of operation and a note was made that it required the largest type of crushing clamp to grasp this dilated limb. The patient died with gangrene of loops of colostomy and generalized peritonitis.

2. M. P. (No. 42-4900) had marked obstruction and dilatation of the bowel at operation and subsequently the colostomy pulled out of the proximal clamp and retracted into the free abdominal cavity. The patient died of generalized peritonitis.

3. B. S. (No. 44-10666) had had a cecostomy done nine weeks prior to admission to the University Hospital. This functioned poorly and at operation the bowel was dilated twice its normal size. The patient died of generalized peritonitis.

4. A. J. (No. 44-12112) had far-advanced tuberculosis and was mentally incompetent. She had an obstruction on admission and had a transverse colostomy nineteen days preceding resection of the sigmoid and urinary bladder. The appendix was removed at the same time because it showed evidence of obstructive changes. This patient died of uremia, wound infection, and cachexia.

5. J. H. (No. 42-10413) developed a urinary tract infection, perinephric abscesses, and became uremic postoperatively. The cause of death was urinary tract infection and uremia.

This review of the deaths graphically illustrates the adage that obstructed bowel should always be properly decompressed before resection is carried out. Rankin[7] recently re-emphasized that obstructed and ulcerated bowel allows virulent organisms to penetrate the bowel, and that even the mere manipulation is sufficient to cause peritonitis.

The closure of the colostomy presented a major problem in this group of resections. Twenty-two patients had 1 closure of the colostomy and one had 3 closures of the colostomy, a total of 25 closures with 12 disruptions, a rate of failure of 48 per cent. There were 11 fecal fistulas in the 23 patients at the time of discharge. When last heard from 6 of these had healed, this leaving only 5 persistent, and one of these may be ruled out because of death from

TABLE V. CAUSES OF DEATH IN MODIFIED MIKULICZ RESECTION

CAUSES	NO.	PER CENT OF TOTAL MORTALITY
Generalized peritonitis	3	60
Wound infection and cachexia	1	20
Bilateral perinephric abscesses	1	20
Total	5	100

recurrence of the carcinoma. Therefore, there have been 4 persistent fistulas in 23 patients, or 17 per cent. There were 5 patients in whom no attempt was made to establish bowel continuity; 2 of these died of carcinoma in the interim, 1 had a recurrence, and 2 have never returned.

RESECTION WITH IMMEDIATE END-TO-END ANASTOMOSIS

There were 21 resections with immediate end-to-end anastomosis of the colon with 4 deaths, a mortality of 19 per cent. Of these resections, 17 were for carcinoma of the colon, 1 for metastatic malignant melanoma, and 3 for carcinoma of the stomach with associated extension to the colon (Table VI).

A brief analysis of the deaths follows (Table VII).

TABLE VI. RESECTION WITH IMMEDIATE END-TO-END ANASTOMOSIS

CONDITION	NO.	DEATHS	PER CENT
Primary malignancy of colon	17	3	17.6
Malignancy with extension to colon	4	1	25.0
Total	21	4	19.0

TABLE VII. DEATHS IN GROUP OF END-TO-END ANASTOMOSES

Generalized peritonitis	3
Cardiac failure	1
Total	4

1. J. K. (No. 39-15433) died on the eighth postoperative day of generalized peritonitis, the signs and symptoms of which became present on the seventh postoperative day. Autopsy revealed dehiscence of the anastomosis with leakage.

2. A. P. (No. 42-1038) was admitted with a rather advanced obstruction. A preliminary decompressing cecostomy was performed and fourteen days later resection and end-to-end anastomosis were carried out. The patient developed an intraperitoneal abscess which was drained on the twelfth postoperative day. Her course was steadily downhill and she died on the thirty-first postoperative day. Autopsy showed dehiscence of the anterior wall of the colocolostomy.

3. T. F. (No. 43-7387) had resection of a malignancy of the splenic flexure. The tumor was difficult to remove and the colon was broken into three times at operation. A wound infection and bronchopneumonia developed postoperatively on the ninth and eleventh postoperative days, respectively. On the twenty-eighth postoperative day an intraperitoneal abscess was drained. The patient died the same day and autopsy revealed a generalized peritonitis with dehiscence of the suture line in two places.

4. E. G. (No. 43-8709), who had diabetes with auricular fibrillation, had a subtotal gastrectomy and colectomy for carcinoma of the stomach with extension to the colon. She developed symptoms of a left femoral embolus on the first postoperative day and this was removed. Death occurred on the second postoperative day from auricular fibrillation and cardiac failure. No autopsy was obtained.

In this group of patients there were 9 decompressing procedures, either transverse colostomy or cecostomy; 7 of these were done prior to the date of resection, and 2 were done at the time of the resection. In this group there was only one death, a mortality of 11.1 per cent.

The decompressions were closed in 5 cases and there were two breakdowns, a failure rate of 40 per cent. One sigmoid colostomy previously performed at

another hospital was removed at the time of resection with a good end result. Three cecostomies closed spontaneously.

Comparison of the modified Mikulicz procedure and the resection with immediate end-to-end anastomosis follows: There was little choice as far as sex was concerned, with 17 women and 16 men in the modified Mikulicz series, and 11 women and 10 men in the end-to-end series. The average age was 59.4 in the Mikulicz series and 61.7 in the end-to-end series. The average number of hospital days was 56 in the Mikulicz group and 43 in the end-to-end group. This includes all days spent in the hospital, both pre- and post-operatively. Of the 28 patients who survived in the Mikulicz group, there were, at the time of the last follow-up, 5 persistent fecal fistulas. If the patient with recurrence is ruled out of this group, there remain 4 with unhealed fistulas or 17.0 per cent of the operative survivals. In the 17 patients who survived the operative procedure with end-to-end anastomosis, there were 2 persistent fistulas present, or 11.7 per cent. There were 13 wound infections in the Mikulicz group, or 39.3 per cent, and 6 wound infections in the end-to-end group, or 28.5 per cent. The mortality has been compared in Table IV. There was an over-all mortality rate of 15.1 per cent with the Mikulicz procedure and 19.0 per cent with the end-to-end anastomosis. In order to gain a better comparison of the trend which the two procedures are taking, the cases are broken down into separate years in Table VIII.

TABLE VIII. COMPARISON OF MODIFIED MIKULICZ PROCEDURES WITH RESECTION AND IMMEDIATE END-TO-END ANASTOMOSIS BY YEARS

	MIKULICZ			END-TO-END		
YEAR	NO.	DEATHS	MORTALITY PER CENT	NO.	DEATHS	MORTALITY PER CENT
1937	1	0		0		
1938	2	0		0		
1939	1	0		4	1	25.0
1940	6	1	16.6	0		
1941	6	0		0		
1942	6	2	33.3	3	1	33.3
1943	4	0		5	2	40.0
1944	7	2	28.6	9	0	
Total	33	5	15.1	21	4	19.0

ANTERIOR RESECTION

An anterior type of resection or Hartman procedure was carried out in 14 cases, with no deaths. This is remarkable when it is remembered that the procedure was used in poor-risk subjects and on low-lying lesions. It is, however, not attended with any of the dangers inherent in the operations which reestablish the continuity of the bowel. There were 10 men and 4 women in this group with an average age of 61.1. Wound infection and disruption occurred in only two instances (Table I).

PALLIATIVE PROCEDURES

There were 19 sidetracking operations for lesions of the right side with 4 deaths, a mortality of 21 per cent. There were 10 sidetracking operations for lesions of the left colon with 5 deaths, a mortality of 50 per cent (Table IX). That palliative operative therapy of carcinoma of the colon does carry a high mortality rate is well recognized. Jones[3] points out that the type of patient who receives this therapy is probably lacking in the essentials of adequate vitamins and proteins due to the general debility which is caused by the disease.

TABLE IX. PALLIATIVE OPERATIONS

	RIGHT SIDE			LEFT SIDE		
PROCEDURE	NO.	DEATHS	MORTALITY PER CENT	NO.	DEATHS	MORTALITY PER CENT
Side tracking	19	4	21.0	10	5	50.0
Cecostomies	3	1	33.3	10	4	40.0
Colostomies	0			39	4	10.2
Total	22	5	22.7	59	13	22.0

We continue to accept the high mortality in this group for the comfort which it affords in the successful cases.

Of the 9 deaths which occurred from sidetracking procedures, 6 were due to generalized peritonitis, 1 was due to shock, 1 to pneumonia, and 1 to mesenteric thrombosis. Of the 5 deaths occurring after cecostomy, 4 were due to peritonitis. In 2 of these cases perforation of the tumor with generalized peritonitis was present at the time of cecostomy and in a third, the tumor perforated at a later date. In one case the cecostomy retracted and a fatal peritonitis resulted; in the fifth case with cecostomy, evisceration occurred and death ensued from shock.

Of the 4 deaths which occurred following colostomy, 2 were due to cardiac failure and the cause of the other 2 was undetermined.

Over and above all of the foregoing groups in which operative procedures were carried out upon the colon, there were 26 patients who had simple exploratory laporotomy with or without biopsy of metastatic areas. Of this group 6 died, a mortality of 23.1 per cent (Table I).

SUMMARY

The operative results of colon surgery for neoplastic disease covering the period between Jan. 1, 1937, and Dec. 31, 1944, have been reviewed. Two hundred twenty-four patients with colon malignancy were treated and the results have been tabulated.

CONCLUSION

1. There is no one operative procedure which can be applied to all neoplasms of the colon.

2. There are an increasing number of resections with immediate end-to-end anastomosis being performed in this clinic.

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OBSERVATIONS ON LARGE BOWEL PERFORATIONS

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IN THE past, analyses of the question of large intestine perforations have revolved principally about the subject of diverticulitis and of its complications. Clinical experience has demonstrated that in any patient over 40 years of age, who gives an antecedent history of lower abdominal discomfort and presents a febrile course and a picture of local or of generalized peritonitis, the problem frequently resolves into the treatment of a complication of diverticulitis. Nevertheless, when one reviews the pathologic material, it is noted that large bowel perforations, as diagnosed clinically, must be interpreted in terms of additional etiologic factors besides diverticulitis and its complications. In the last ten years in this hospital, among a total of 1,400 necropsies there have been recorded nineteen cases (1.35 per cent) of large bowel perforations, each with the complication of extraluminal abscess formation, localized peritonitis, or generalized peritonitis. Ten, or slightly over one-half of these, were attributable to a perforation complicating diverticulitis. In six cases a large bowel malignancy was present. A single instance is recorded of ovarian carcinoma metastasizing to bowel wall and producing communicating ileal and sigmoidal perforations. In the two remaining autopsies, mechanical perforations from within were found and these will be discussed in detail further on. We have had no autopsies in cases of perforation secondary to cecal tuberculosis or to ulcerative colitis. Examples of the former are encountered with greater frequency in older treatises on this subject. Regarding chronic ulcerative colitis, Rankin, Bargen, and Bouie reported the incidence of perforation to be 3.4 per cent in their large series of patients with this disease.

The cases in which autopsies were done, cited here in detail, are exemplary of the subject presented. All are recordings of personal experiences in the past year.

DIVERTICULITIS AND PERFORATION

CASE 1 (No. 102537).—A 59-year-old white man, an investigator, was admitted to the hospital Nov. 27, 1944. Four weeks prior to admission he had experienced a chill, followed by persistent diarrhea. Ten days after this episode there commenced lower abdominal pain, chiefly on the left side. The diarrheal stools became reduced and never exceeded two or three tablespoonfuls. Later he noted abdominal distention. Anorexia and weakness were marked and a weight loss of fifty pounds was attributed to the present illness. The patient had been bedridden for seven days. Prior to admission, a barium clysma performed by his local physician had demonstrated an obstructive lesion of the sigmoid and diverticulosis. The family history was noncontributory. The past history was not significant except for ankle swelling of one month's duration. Physical examination revealed an acutely ill patient complaining of severe abdominal pain. The blood pressure was 90/70, the temperature was 102.4° F., and the pulse 120. An edema of the extremities and trunk was noted. The abdomen was domelike an distended. Marked tenderness and rigidity were present over the left lower quadrant. The colon down to the sigmoid was distended and visible through the abdominal wall. The laboratory data included: hemoglobin 80 per cent, red blood cells 3.9 million, white blood cells 8,900 with 78 per cent polymorphonuclear leucocytes including 26 per cent immatures; the urine showed 3 plus albumin and numerous casts; urea nitrogen

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Fig. 1.—Roentgenogram of lesion in patient in Case 1. Obstruction and probable extraluminal extravasation of barium are exhibited.

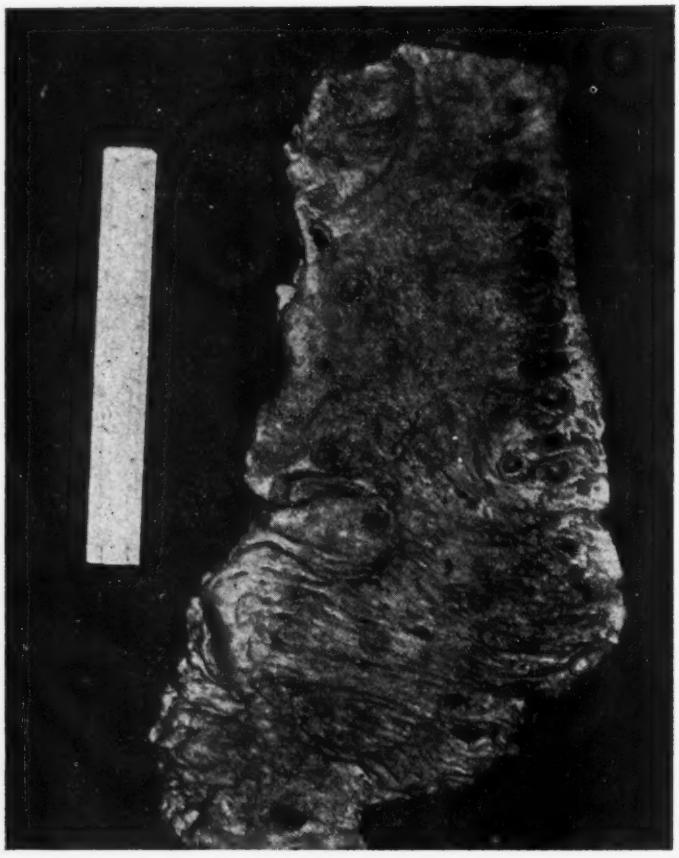

Fig. 2.—Prepared and mounted pathologic specimen from Case 1, showing columns of diverticula. The obstructive stenosis of the lumen is demonstrated at the lower area. Multiple perforated abscesses were demonstrable.

was normal. The clinical diagnosis was intestinal obstruction due either to a sigmoidal neoplasm or to diverticulitis. The day following admission a cecostomy was performed under local anesthesia to relieve the obstruction. Despite adequate drainage through the cecostomy, the patient's course was unfavorable, and he died on the second postoperative day.

The autopsy performed on the day of death demonstrated an acute generalized fibrinopurulent peritonitis; all intraperitoneal recesses contained pus, and small and large bowel loops were coated with heavy layers of fibrin. The large bowel proximal to the sigmoid was enormously distended, and the wall thinned and friable. The lower descending colon and the sigmoid were fixed in a thickened plastic mass along the promontory of the sacrum. The mesenteric fat surrounding the bowel was firm and indurated, and many pus accumulations were encountered. Mucosal diverticula were present throughout the entire large bowel as far proximally as the cecum; these were as large as 1 cm. in diameter and usually contained an inspissated fecal plug. Several of the diverticula in the descending colon and sigmoid were covered with thick, indurated tissue with here and there a fresh fibrin surface covering. Occasional areas of frank suppuration were present within these diverticula. At a point 25 cm. from the anal margin, the thickening and induration about the bowel wall were maximum and a distinct stricture was evident on intraluminal exploration and probing; this was produced by the stenosing perisigmoidal, adhesive mass.

Comment.—This case is reviewed in detail because it illustrated significant features and sequences of diverticulitis with its complications and sequelae. First, there was an extensive anatomic alteration in that the diverticula were not limited to the sigmoid as is usually the case, but extended completely around the large colon to the cecum. Second, there were exhibited several of the possible clinical and pathologic complications of diverticulitis: (a) gross and microscopic evidences of a peridiverticular chronic inflammatory reaction; (b) abscess formation; (c) perforation of inflamed diverticula accounting for generalized peritonitis; (d) progressive intestinal obstruction with stenosis as the result of chronic, repeated, perisigmoidal inflammatory insults. Another possible complication, namely, fistula formation, may well have resulted had not the obstruction and perforation terminated the life of this patient. It is not uncommon that a sealed-off peridiverticular abscess ruptures into an adjacent viscus or externally on the skin. That diverticulitis is the most common offender for sigmoidovesical fistulas is well recognized. The most uncommon complication of diverticulitis is metastatic suppuration.

This case is illustrative of the seriousness of the disease and of its complications. The literature is abundant with statistics on diverticulitis and its sequelae but these vary widely depending upon how each series is recorded. For ample reviews the reader is referred to the publications of Ochsner, of Arnheim, and of Young and Young. Compilation statistics would seem to have indicated that diverticula exist in approximately 3 to 5 per cent of all colons, but it must be remembered that this figure would be a good deal higher in patients over 40 years of age. For all clinical purposes diverticulitis and its complications are practically unknown before the fifth decade. In the compilation statistics of Young and Young, diverticulitis developed in 34 per cent of colons with diverticula. Arnheim's review noting 834 compiled cases of diverticulitis quoted the incidence of abscess formation to be 4 to 39 per cent in respective individual reports, with a total average of 19 per cent; and on a similar basis the incidence of peritonitis varied from 0.8 to 25 per cent with a total average of 12 per cent. Despite these wide variations in reports, the over-all significance and relative frequency of perforative complications are established. One feature of the disease which is distinctly illustrated by statistics is the fact that there is absolutely no etiologic relationship between the incidence of sigmoidal carcinoma and diverticulitis.

This case demonstrates the difficulty encountered in the differential diagnosis of obstructing lesions of the sigmoid colon. It was originally felt from the barium clysma study that probably a neoplasm was being dealt with. As high as a 15 per cent radiologic error is quoted in differentiating sigmoidal obstructive peridiverticulitis and malignancies. One must be aware that malignancies and stenosing sigmoiditis secondary to diverticulitis occur in the same age group and that therefore each case must be individualized. A carefully taken history possibly revealing cyclic febrile episodes with lower abdominal symptoms in the past would favor the diagnosis of purely inflammatory pathology.

CARCINOMA AND PERFORATION

CASE 2 (No. 101922).—A 59-year-old white man, a newshawk, was admitted to the hospital with the complaint of right lower abdominal pain of four weeks' duration. The pain was intermittent in nature, probably noncolicky, and occasionally radiated into the scrotum. There was no vomiting and daily bowel movements were normal. The patient had always felt well except for an undefined back condition for which x-ray treatments had been given one year before admission. He had allegedly contracted a chancre at the age of 29 but had never received treatment. The family history was not significant. On physical examination the patient was obese and appeared moderately ill. The temperature was 100.2° F., the pulse 80, and the blood pressure 120/72. Pertinent findings were confined to the abdomen where an orange-sized, firm, tender mass was felt in the right lower quadrant. Laboratory data included: hemoglobin 69 per cent, red blood cells 3.4 million, white blood cells 12,000 with 72 per cent mature polymorphonuclear leucocytes; urea nitrogen was 14.0; the Wassermann was negative; the urine showed a trace of albumin and occasional red and white cells; the stool guaiac was negative for blood; the sedimentation rate was 42.0 mm. in one hour. The barium clysma studies demonstrated an obstructing lesion of the cecum, interpreted as follows: "The lesion probably represents a carcinoma of the cecum but the possibility of an intussusception or an appendiceal abscess must also be considered."

The patient was prepared for operation with the usual measures, including transfusions and sulfasuxidine. At the laparotomy performed on the tenth day following admission, there was a large, fixed, ileocecal mass extending posteriorly and toward the pelvis. This was regarded as an inoperable malignancy and a palliative ileotransverse colostomy was performed. On the third postoperative day a wound dehiscence was noted; through-and-through closure of this was done immediately under general anesthesia. The ensuing course was unfavorable, and he died on the third postoperative day following wound closure (sixth day following laparotomy).

At autopsy performed the following day, there were no evidences of local or generalized peritonitis; all peritoneal surfaces were smooth and glistening, and no intraperitoneal abscess pockets were encountered. The wound and anastomotic sites were well sealed off. A bulging retrocecal mass was present, and when the peritoneum of the right lateral gutter was stripped off, a tense, extraperitoneal abscess overlying the inner aspect of the iliacus muscle was entered. An estimated 500 c.c. of turbid pus was evacuated from the abscess cavity. The abscess was in direct communication through a pin-point sized opening with the center of a large, fungating, polypoid carcinoma of the cecum. Elsewhere, along the course of the large bowel and rectum there were observed several mucosal polyps, the largest measuring 1 cm. in diameter. Microscopic examination demonstrated the cecal malignancy to be a mucoid adenocarcinoma, probably Grade III. In addition, the largest of the several adenomatous polyps proved to be an early Grade I adenocarcinoma. There were no microscopic evidences of lymph node metastases in the drainage fields of either of the two malignancies.

Comment.—This case illustrates a large bowel neoplasm with perforation and secondary suppuration. It is not the uncommon experience of the surgeon dealing with large numbers of colon malignancies to have the disease come to his attention for the initial time because of symptoms referable to perforation of the tumor with attendant abscess formation or peritonitis. It has been estimated that as many as 25 per cent of all colon malignancies come to medical consultation for the first time because of perforation. Rankin, Bargen, and Bouie noted that the splenic flexure had been the most frequent site of perfora-

tion. In our autopsies of the last ten years there are recorded thirty-seven cases of large bowel malignancy. In six of these there was a perforation of the carcinoma. Thus, in our experience, 16 per cent of colon malignancies have perforated before treatment. This figure is based on comparatively few cases and is probably high, for the patient with a perforation bears a grave prognosis and is more likely to succumb in the hospital. Four of the perforations of the large bowel associated with carcinoma were in the sigmoid and two were in the cecum. In a series from the Mayo Clinic of 1,502 consecutive cases of colon malignancy, at operation 144 (9.4 per cent) were regarded as complicated by perforation. Instances are recorded of fecal fistula associated with a perforated carcinoma of the large bowel. This probably would have been the situation in the case just cited had the abscess dissected extraperitoneally and decompressed on the anterior abdominal wall.

The prognosis in perforated large bowel carcinoma is extremely discouraging. Even the initial operative procedure of a proximal, decompressing colostomy or cecostomy usually with drainage to the point of perforation or abscess formation bears a high mortality; also, when the tumor has reached the anatomic stage of perforation, it is usually inoperable because of fixation and/or metastatic spread.

INTRALUMINAL MECHANICAL PERFORATION

CASE 3 (No. 96102).—A 71-year-old white housewife was in this hospital one year prior to the present illness. At that time the diagnosis was hypertensive cardiovascular disease and diabetes, and she was discharged on a maintenance dose of digitalis and a controlled diabetic diet with 25 units of protamine zinc insulin. Six days prior to this admission she experienced sudden lower abdominal pain and had five to six bowel movements a day. She took no food and is said to have stopped regulating the diabetes. During the two days preceding admission she vomited five times and noticed bright red blood in the stools. Crampy pain, localized to the lower quadrants, had continued. On physical examination the temperature was 100° F., the pulse 108, respiration 30 and labored; the blood pressure was 130/75. She appeared acutely ill and dehydrated. There were no signs of cardiac decompensation. The lower abdomen was distended with dilated and hyperresonant bowel. There was no shifting dullness, no obliteration of liver dullness. The left lower quadrant was acutely tender and spastic. No masses were palpable. Rectovaginal examination yielded no distinct findings. The admission laboratory data included: white blood count 7,680 with 82 per cent polymorphonuclear leucocytes of which 55 per cent were immatures; the urine showed a trace of albumin, 1 per cent sugar, strongly positive acetone, and occasional white blood cells and red blood cells. It was felt that the patient had a peritonitis possibly due to perforation of an obstructing large bowel malignancy. The diabetes was controlled by hourly urine studies and parenteral fluids and insulin; an exploratory operation was performed fifteen hours after admission. Thick pus was encountered in the abdominal cavity; this grew *Bacterium coli* subsequently. The left Fallopian tube was dilated and convoluted, but there was no torsion. The adjacent large bowel seemed indurated. Otherwise there was no evident pathology. Penrose drains were inserted, and the operation terminated. Postoperative measures were supportative and included parenteral digitalization and fractional urine diabetic control. However, dyspnea and toxemia supervened, a shocklike picture arose, and the patient succumbed fifty-two hours after operation.

At autopsy it was seen that the peritonitis had apparently resolved since operation, for the small bowel and visceral surfaces were smooth and glistening; there was no free fluid. Partially enveloping the sigmoid in the left gutter was a well-circumscribed abscess. Adjacent to this an edematous and hemorrhagic left tube was adherent to the lower sigmoid. When the uterus was elevated forward, firm adhesions were identified extending from the posterior leaf of the left broad ligament to the sigmoid. Upon opening the sigmoid along the anterior longitudinal band there was encountered, at the level of the pelvic brim and 25 cm. above the anal margin, a bone resembling a fowl bone measuring 5½ cm. in length. This bone was impacted obliquely across the lumen with its bifurcated left edge imbedded through the sigmoid wall adjacent to the area where the Fallopian tube was adherent to the colon;

the other bone edge had penetrated the opposite side of the bowel into a well-sealed-off perisigmoidal pocket. The mucosa surrounding each area of penetration was necrotic. The left gutter abscess extended upward from the penetration of the bifurcated edges of bone on the left side. In addition to the gastrointestinal tract pathology, other findings included marked congestion of the lungs and bilateral hydrothorax, advanced arteriosclerotic heart disease, and cardiac cirrhosis of the liver.

Fig. 3.—Specimen from Case 3 showing perforating bone in situ, in sigmoid. A penetration was observed at each end of bone.

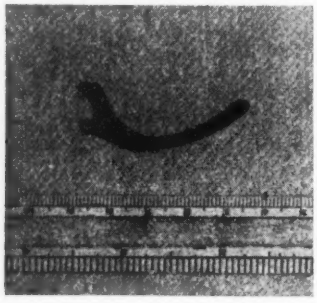

Fig. 4.—Transversely impacted bone extracted from sigmoid of patient in Case 3.

Comment.—This case adds another interesting one to the long list of reports on complications produced by ingested foreign bodies. The patient gave no history of having swallowed the bone, which appeared as to be some sort of fowl bone. It is remarkable that the foreign body, in this instance much elongated and with sharp, bifurcated edges, traversed the natural fixation points and narrowed ostia of duodenum and ileocecal regions, to finally impact transversely in the redundant sigmoidal fold. In most of the case reports of foreign bodies perforating the colon, the offending agent was usually of smaller dimensions. Had not severe myocardial insufficiency supervened, it is not unlikely that this patient might have survived the perforation, for, at necropsy the peritonitis was resolved into well-localized abscess formation. It has been the

experience of authors who have reported colon perforations due to foreign bodies that the prognosis in such perforations has been excellent, in contrast to those of the stomach and upper intestinal tract.

Henderson and Gaston, in 1938, reported on fifty-seven collected cases of foreign body perforations of the gastrointestinal tract and added nine of their own cases. They reviewed in detail the entire subject of the fate of ingested foreign bodies. They concluded their analysis with the recommendation that operative investigation is indicated when a twenty-four hour period of observation has revealed no progress in the passage of the foreign body with relation to adjacent viscera. In their collected series of perforations, a large number occurred in the stomach. Macmanus, in 1941, reviewed cases of gastrointestinal perforations caused by foreign bodies. He assembled ninety-three cases from the literature and contributed two of his own, one of which was a perforation by a piece of wire, of a loop of bowel incarcerated in a hernial sac. Seventy-three per cent of the perforations were in the lower ileal and cecal region, and a Meckel's diverticulum was a frequent site of penetration. Fifteen instances of colon perforation are recorded, and in these the prognosis was generally excellent. The list of offending agents in gastrointestinal perforations by ingested foreign bodies is an imposing and familiar one, with toothpicks and fishbones probably being the most frequent. In children the swallowed opened safety pin provides a not unusual problem.

The treatment of large bowel perforations by foreign bodies is similar to that of perforations secondary to primary colon disease. Early and adequate intraperitoneal drainage, proximal decompression (colostomy), and meticulous attention to the postoperative adjuncts of decompression (Miller-Abbott tube) and of blood chemistry and fluid balance control are the weapons at command. Rarely is it possible to exteriorize the perforated segment of bowel.

CASE 4 (No. 39213).—This was the fifth admission of a 26-year-old white man, an artist, who came to the hospital acutely ill. He offered the history of having had "loose bowels" for several days, which he had attempted to control twenty-four hours before admission with a high enema. The latter procedure was followed within one-half hour by the onset of sudden and diffuse abdominal pain. The pain persisted and was poorly localized but soon became so severe that he sought hospitalization.

This patient was first seen in the hospital in October, 1933, for complaints referable to an anal fistula, presumed to have been syphilitic in origin because of a 4 plus blood Wassermann. This lesion failed to respond to antisyphilitic treatment. On a second admission, in May, 1934, a proctoscopic examination revealed a broad anorectal scar; the biopsy report was chronic ulcerative proctitis with polypoid hypertrophy of mucous membrane; there were no evidences of tuberculosis and no vascular changes suggestive of syphilis. A sigmoidostomy was performed to by-pass the fecal stream and to allow for adequate local rest and irrigation therapy of the rectal pathology. On a third admission, in March, 1937, the sigmoidostomy was closed operatively. On a fourth admission, in December, 1944, there were complaints and findings suggestive of glomerulonephritis. Physical examination on the final admission revealed a severely ill patient. The temperature was 100.6° F.; the pulse was 140; the blood pressure was 116/78. The abdomen was boardlike and exquisitely tender throughout. Within a few hours of admission, a laparotomy was performed. Cloudy, yellow fluid with suspended particles filled the abdominal cavity; fecal material was exuding from a perforation in a small gangrenous patch of the lower anterior sigmoid. A decompressive transverse colostomy was performed, and drains were inserted to the site of perforation. Postoperatively, the patient exhibited severe renal decompensation, and he expired in uremia on the sixth postoperative day.

At autopsy, the margins of the recent transverse colostomy were well sealed off. The lower abdomen and pelvis contained a large amount of hemorrhagic, purulent fluid and here the bowel loops were coated with fibrin. At the rectosigmoid junction 18 cm. from the anus there was a gangrenous zone along a 2½ cm. length of anterior bowel wall; several elongated, through-and-through disruptions in the wall were seen here. Above (proximal to) this re-

gion, the sigmoid was bound by dense adhesions to the anterior abdominal wall underlying the scar of the old sigmoidostomy. When these adhesions were separated it was seen that the lower sigmoid was rotated and angulated in the anteroposterior plane in such fashion that it formed a complete S malformation upon itself within a very limited space; the two limbs of the S were tightly compressed and the total length of reduplicated sigmoid here was only about 3½ cm. This anatomic alteration had produced a ball valve type of retrograde obstruction of the lower sigmoid with the rectosigmoid below corresponding to a large redundant sac. It was at the anterosuperior portion of this sac that the gangrenous patch was present. There were no microscopic manifestations of specific lesions (tuberculosis or syphilis) in the rectal or sigmoidal walls or in the supporting connective tissues. Finally, there were microscopic evidences of a fulminating, malignant nephrosclerosis.

Comment.—This case may be classified with the previously cited one, inasmuch as it represents rupture of the rectosigmoid as a complication of intraluminal mechanical insult. Rupture by direct contact of an extremely long enema tip cannot be entirely eliminated as a consideration here, although the distance of the perforation from the anal margin would speak against this possibility. However, from the autopsy findings, it may be presumed that the combination of an old postoperative retrograde obstruction of the sigmoid and the sequence of a generously administered enema followed by onset of severe abdominal pain furnish evidences of fluid pressure rupture of the rectosigmoid. Cases of rupture of the bowel by an enema are recorded. It would seem that previously existing retrograde, segmental obstruction as was present here would be necessary to make possible rupture by a vigorous enema, for the gradual distensibility of the entire colon is enormous. In the case under consideration, the enema must have flowed in under very great pressure.

In 1931, Burt recorded from the literature and from his own cases a total of forty-four pneumatic ruptures of the bowel; the sigmoid was the most frequent site of rupture. He gathered some interesting experimental evidence on the air pressure necessary to rupture various segments of human bowel removed at autopsy. The average pressure required to rupture sigmoid bowel was 4.99 pounds per square inch. In the adult the ileum was the most resistant segment, an average of 8.36 pounds per square inch having been necessary to disrupt all layers. Higher pressures were generally necessary to produce rupture in the bowel of children. Burt's experiments were carried out at a fixed rate of air filling of the closed segment of bowel, namely, .38 pounds per second. It would seem that the rate of increasing intraluminal pressure would be an additional variant in determining the pressure at which the bowel ruptures.

SUMMARY

1. Experiences with large bowel perforations are analyzed.

2. Nineteen autopsies were recorded over a ten-year period. Perforation associated with diverticulitis accounted for ten of these deaths, seven were due to malignancy, and the remaining two to perforation by mechanical agents within the lumen.

3. Four recent autopsies in which large bowel perforations were revealed are cited critically and in detail, and a clinicopathologic survey is made in each instance.

4. The morbidity and mortality in diverticulitis complicated by perforation are distressingly high.

5. Probably between 10 and 20 per cent of primary large bowel malignancies first come to medical attention with the complication of perforation. The prognosis is extremely grave in this group.

6. Two unusual cases of perforation of the sigmoid due to intraluminal insult are recorded: one was due to perforation of an impacted fowl bone in a patient who gave no history of ingestion of the foreign body. The second case was one of rupture of a rectosigmoid following a vigorously administered enema; the lower sigmoid was anatomically sharply angulated as a result of an old operative procedure.

7. Treatment of perforation of the large bowel from any cause is essentially the same: early and generous drainage with a minimum of manipulation of the site of penetration and a proximal decompressive colostomy are the indicated surgical measures.

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SMALL BOWEL STRICTURE FOLLOWING IRRADIATION THERAPY FOR CARCINOMA OF THE FUNDUS UTERI

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DAMAGE to the intestine following irradiation therapy for cervix cancer is well known. The attention of the profession was first called to this complication in the early 1930's by Jones[1] in this country and Pemberton,[3] Jeanneney and Berard,[4] and others abroad. Since then, several careful analyses of series of cases have been reported. In most instances the terminal sigmoid and rectum are affected. There is a proctosigmoiditis, with symptoms of diarrhea, tenesmus, blood, mucus, etc. Later obstructive strictures may ensue. Although less common, all series contain a few cases in which the terminal ileum was damaged, causing more violent symptoms of small bowel obstruction, nausea, abdominal pain attacks with distention, etc.

In most of these cases, the damage has followed heavy radium dosage. Therapeutically, the effects of radium are produced within the confines of an arc 5 to 6 cm. in all directions from the cervix. A heavy loop of sigmoid may fall into the pelvis, a loop of ileum similarly may happen to be in the pelvis, or had been bound down in the pelvis because of adhesions from a previous pelvic operation or old pelvic inflammation.

Another type of damage is widespread ileal damage (in contrast to localized lesions) thought by McIntosh[2] "undoubtedly a product of heavy x-ray dosage, almost invariably through large portals 12 by 16 cm." Here there is widespread fibrosis with multiple adhesions of the small bowel widespread in the abdominal cavity. Martin[5] has shown that in dogs "irradiation of the whole abdomen produced various grades of toxemia, many of which were fatal . . . true roentgen sickness in many instances resulted from the effect of roentgen rays upon intestinal mucosa." Martin further remarked that "intestinal damage is still produced when vigorous attempts are made to cure advanced cases of cancer of the uterus with roentgen rays." Symptoms may start from two months to five years or longer after treatment has been given. Although, as stated, most instances of this peculiar damage have followed heavy irradiation, in an occasional instance it has followed years after very light irradiation. One of Schreiner's[6] patients developed obstruction necessitating small bowel resection two years after treatment. "The dosage was not excessive, a small dose of roentgen rays, and two 400 mg. hour intrauterine radium applications."

Recommendations to avoid these unfortunate sequelae have been various. They include (1) weaker radium dosage, spread over longer time periods; (2) avoidance of heavy treatment dosages in attempts to cure far-advanced cases; (3) measures aiming to get the coils of ileum or sigmoid out of the pelvis during treatment: full urinary bladder, high Trendelenburg position (difficult to carry out routinely with twenty to thirty daily treatments or the present-day million volt machine); (4) careful preliminary investigation of patients who have had previous pelvic operations and avoidance of therapy if the bowel is suspected of being fixed to the posterior surface of the uterus, perhaps laparotomy and inspection before treatment is instituted. Meigs[7] thought-

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fully remarked that one-half of their cases had been in the early operable group; perhaps operation would have been safer than irradiation.

As to treatment of these bowel sequelae of irradiation, the tenesmus, diarrhea, etc., which are frequent concomitants of the usual course of therapy to cervix cancer, usually subside in several weeks. Some patients with narrowing have been treated with bland diet and bland rectal irrigations, and have become comfortable after several months even though narrowing still persisted. An increasing number have come to operations, such as permanent colostomy, liberation of adhesions, resection of sigmoid or ileum.

Strictures have been reported two months to five years after treatment. In such cases it may be very difficult to tell whether the cramps, abdominal distention, nausea, etc., are due to abdominal extention of the carcinoma or slowly forming strictures. The only differentiation is careful observation; if the patient's general health remains good and does not go downhill as a cachetic terminal malignancy should, operative exploration is warranted. It has been observed that the barium meal does not always show the "multiplicity or extent of these small bowel lesions" (Pightal[8]). Jones also commented on these difficulties in clinical diagnosis in 1935.

In practically all of the reported cases the pathologic condition has followed treatment for cervix cancer. In conversation with several radiologists, it was doubted that irradiation treatment for cancer of the fundus would produce radiation stricture. Nevertheless, three case reports of bowel damage following treatment for corpus carcinoma were found. A fourth is herewith added in which bowel damage followed radium treatment for benign hyperplasia.

Aldridge[9] reported that one intestinal injury (proctosigmoiditis) followed treatment of forty-seven patients with carcinoma of the fundus uteri. The cell type was grade 3.

Schreiner,[6] reporting five cases of bowel damage, stated that the second case was that of a uterine carcinoma, and the patient developed obstruction in the sigmoid which required colostomy eight years after treatment.

Cascaden, Kasabach, and Lenz,[10] detailing fifteen case reports, described Case 9 as follows: Adenocarcinoma of the corpus stage 1 League of Nations. Treatment factors were: Radium into uterus 100 mg. 30 hr. = 3,000 mg. hr., 35 days later 112 mg. in uterus 24 hr. = 2,700 mg. hr., 19 days later roentgen treatment—2 anterior fields 10 by 10 cm., 52 Rx in 63 days; 19 days later roentgen treatment—2 posterior fields 10 by 15 cm., 52 Rx in 63 days. Daily dose 100 r, total 9,200 r. Grand total 5,700 mg. hr. and 9,200 r in 110 days. Eight months after beginning treatment, and four months after end of treatment there was diarrhea, bloody stool, and signs of partial obstruction. The obstruction was caused by a loop of sigmoid bound to bladder and rectum.

Pemberton[3] reported a woman, aged 43 years, who had had menorrhagia for one year. She had had a laparotomy with bilateral salpingectomy seven years before. A small fibroid was felt in one cornu of the uterus. Rapid sections from the curettage showed endometrial dysplasia. Radium, 100 mg., with 0.5 mm. silver and 1 mm. brass was inserted into the uterine cavity for twelve hours. The patient was admitted to the hospital sixteen months later. There had been occasional attacks of pain and discomfort in the rectum. Five days before admission "something broke in the lower abdomen and there was fever and discharge." After no improvement in three weeks, a laparotomy was performed. A loop of sigmoid was densely adherent to the back of the fundus uteri, and there was an abscess containing 2 to 3 ounces of pus between them. The raw sur-

faces were sutured over and hysterectomy was performed. Their conclusion was that it was a mistake to insert radium into the uterus of a patient who had had a previous pelvic operation.

CASE REPORT

In the following patient the damage followed irradiation treatment for carcinoma of the fundus uteri. As these things usually go, there undoubtedly have been many more cases of bowel damage following irradiation treatment for carcinoma of the fundus that have not been reported. Also, probably there may be other reports in the literature which we have not encountered. Nevertheless, the rarity warrants reporting.

Although radium was given, the damage apparently followed the protracted courses of x-ray therapy, since at operation there was widespread involvement of the entire small bowel and other abdominal contents. It was also clinically difficult to differentiate between extensions intra-abdominally of carcinoma of the fundus and adhesions causing the patient's symptoms. As is well known, the extension of carcinoma of the cervix is into the broad ligaments and around the ureters. Many of these patients die from strangulation of the ureters, and at necropsy it is found that the carcinoma has involved the tissues within 1½ to 2 inches of the cervix only. On the contrary, carcinoma of the fundus is notorious for extension into the general abdominal cavity, causing multiple masses, multiple foci of obstruction, liver deposits, etc.

CASE 1.—Mrs. M., aged 49 years, was seen for the first time July 28, 1944. Her menopause had been completed seven years previously. She was perfectly well until June, 1943 (six years). At this time she complained of spotting, and on one occasion suddenly passed large clots of blood. There was also fatigue and weakness. She was advised to have a dilatation and curettage for diagnosis and shortly was hospitalized for this purpose. The curettings showed adenocarcinoma of the fundus (July, 1943). Because of some doubt as to the cardiac reserve, operation was not done. She was given deep x-ray therapy, beginning Aug. 10, 1943. She received treatments daily for six weeks, ending in September, 1943. Then in February, 1944, radium was inserted into the uterus for one week. April 10, 1944, another deep x-ray therapy course of daily treatments for five or six weeks was instituted, ending May 16, 1944. She had not felt well since the end of this treatment. Diarrhea started in April, 1944. Soon the abdominal pain and cramps started. For the next two months, there was marked weight loss and great anorexia associated with abdominal discomfort and pain. For the next six weeks, that is since June 6, 1944, bowel movements were difficult, although for the next week constipation was somewhat less. The pain was rather generalized over the entire abdomen, but more marked in the left lower quadrant. When first seen at home, April 28, 1944, the patient presented an extreme clinical picture. She was very pale and pasty looking, lying very weakly in bed, unable to sit up, and was breathing very heavily. She was taken to Harper Hospital that night. She was quite dehydrated and anemic (hemoglobin 57 per cent, red blood cells 2,740,000, an irregular low-grade fever, and white blood cells 12,000). Abdomen showed extensive discoloration from x-ray therapy over both lower abdominal quadrants. There was some tenderness in the left lower quadrant. Pelvic examination was unsatisfactory, but the uterus was perhaps 1½ to 2 times normal size, was not very mobile, and there was some tenderness in the left adnexal region. In the hospital, the anemia improved under treatment for dehydration and transfusions. The low-grade fever and pelvic tenderness disappeared under penicillin therapy. The hemoglobin rose to 69 per cent, with 3,140,000 red blood cells, 4,750 white blood cells, and her bowels moved more freely. She was discharged Aug. 7, 1944, with a diagnosis of carcinoma of the fundus uteri with peritoneal extension and metastases.

She made weekly or bi-weekly visits to the office for follow-up study. She felt better. Bowels moved somewhat more freely, and the pain in the left lower quadrant gradually subsided. At one time, the pain and pelvic tenderness increased, but following a short course of penicillin she felt improved. She continued to have backaches, and the red blood cells hovered around 3 million. Pelvic examination revealed the uterus gradually subsiding to relative normal size. However, she did not quite regain her strength.

About Nov. 1, 1944, pain somewhat like the original cramps started again. She felt tired, but usually had good bowel movements. She had gained weight, about fifteen pounds since treatment, but was still twenty pounds below her usual pre-illness weight. On Dec. 3, 1944, she was suddenly seized during the night with very severe abdominal cramps and vomiting. These continued during the night. She was again taken to Harper Hospital. Examination showed seizures of very severe abdominal cramps, coming in spasms associated with nausea. Bowels had not moved for twenty-four hours. Abdomen was not tense but during the seizures there seemed to be tenseness throughout. Seizures were very painful. This was an attack of intestinal obstruction. The Levin tube brought forth some foul-smelling intestinal contents. Miller-Abbott tube was then introduced, and it descended five or six inches past the jejunum. Bowels did not move for five or six days, then enemas became effectual and the patient felt better. X-ray examination with emphasis on the small bowel showed moderate dilatation of the small bowel loops, many of them filled with gas. The barium passed slowly beyond the upper jejunum and at the end of six hours barium was still in the upper small bowel. At the end of twenty-four hours, the film showed barium still distributed throughout the small bowel. There was some irregularity of the small bowel pattern in the pelvis. Although there was marked hypermotility of the barium meal with much stasis in the small bowel, some of the barium apparently passed into the large bowel and was seen in this twenty-four-hour film in the region of the cecum at the colon. X-ray diagnosis was incomplete small bowel obstruction. The Miller-Abbott tube was removed Dec. 12, 1944. Bowels then moved normally, she felt well, and since the obstruction was relieved she was discharged on Dec. 17, 1944. The diagnosis was intestinal obstruction. It was still uncertain whether this was due to metastatic deposits inside the abdomen or whether the obstruction was due to x-ray damage to the small bowel.

Another attack of violent cramps and constipation sent the patient to the hospital two weeks later (Dec. 29, 1944). However, within one or two days she was having normal bowel movements and no cramps, and she was again sent home on limited nonresidue diet. At this time the hemoglobin was 88 per cent and red blood cells 4,240,000. Evidently, she was not losing ground or becoming anemic.

She again felt well and bowels moved for two weeks but about Jan. 20, 1945, suddenly during the night, she had the old sharp abdominal pain. Pains came every five or ten minutes lasting all day. Some of these were "as if she were cut in half." She stated that if she "could have a real bowel movement," her troubles would end. She volunteered information that she had not had a normal evacuation "since she had had that old therapy in 1943 and 1944." Even when they did move, the evacuations were in small pieces and she always had to take oil or milk of magnesia. There had been no diarrhea since a few weeks following the last course of therapy. She continued to feel nauseated after eating. Examination, Jan. 26, 1945, revealed a soft abdomen with no definite abdominal tenderness. Because of the repeated bouts of small intestinal obstruction and the maintenance of her general health, it was decided that the period of observation should be ended. The probability was that the obstruction was due to adhesions and not necessarily extension of the malignancy. Exploratory operation was advised. This was done on Feb. 1, 1945. As the abdomen was entered, the fat seemed fibrous and thickened, the fascial layer was not clearly defined, and the muscle was a dark chocolate color. It appeared to be evidence of rather extensive previous x-ray therapy. The peritoneum was opened. The small intestine was thin and pale and the blood vessels were not very prominent. The uterus was normal in size. The bladder folds were somewhat adherent. Posteriorly, the sigmoid was adherent to the posterior surface of the uterus in the cul-de-sac. The adnexa were bound down low in the pelvis and were small and atrophic, the adhesions being quite dense. Lightly separating the sigmoid from the posterior wall of the uterus, a small nick was made in it. This was immediately sutured with three mattress sutures. Further exploration of the deep pelvis revealed a matting down of the adnexa posterior to the uterus. The adnexa were small, shriveled, and fibrous and seemed to show the effects of x-ray therapy.

The small bowel was then explored. The terminal ileum for about twelve inches was somewhat thicker than the upper region. At one point, about ten inches from the cecum, there was a dense adhesion binding the small bowel to the anterior right peritoneum far out toward the cecum. It seemed as if this was sufficient to cause kinking, which was responsible for the patient's symptoms. In the upper portion of the abdomen, the omentum in the region of the liver was also densely adherent to the undersurface of the liver and to the parietal peritoneum.

The whole picture was one of post-x-ray therapy damage with extensive changes, in the wall of the small bowel, pelvic organs, omentum, and peritoneum.

Convalescence was eminently satisfactory. Normal bowel evacuations started immediately. She was discharged on the seventh day. Since leaving the hospital, she has "felt like a different person." She takes mineral oil occasionally, once a week, whereas before it was necessary to take it every day. When last seen May 21, 1945, she had normal bowel movements (with occasional mineral oil, as stated). She has regained her strength, her appetite is excellent, she can do her own housework, and has gained twenty pounds since the operation. Examination showed a totally different looking individual, robust and healthy appearing. The abdomen was soft, and there was no tenderness. Pelvic examination was negative.

SUMMARY

A case is reported in which severe generalized small bowel damage, with intestinal obstruction due to adhesions, followed prolonged x-ray therapy for carcinoma of the fundus of the uterus.

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AN INTESTINAL SPUR-CRUSHING CLAMP

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CRUSHING the spur is an essential intermediate step in the Mikulicz series of operations frequently used for colon resection. This procedure destroys the assembled double medial wall of the two-barreled colostomy to the end that intestinal content may flow from the afferent limb directly into the efferent intestinal tube. Although any ordinary heavy hemostat may be used to destroy the partition through its entire length, this act is more effectively accomplished by clamps specially designed for the purpose. The most acceptable of such enterotribes have their jaws meet in parallel approximation. A thumb turnscrew or ratchet arrangement provides for a gradual and slow increase of pressure. Usually the crushing surfaces have grooves in their longitudinal or transverse direction to provide some nonslip quality when applied.

Two deficiencies of these standard enterotribes, however, detract from their correct performance. The instrument frequently slips off the thick intestinal septum unless it is immediately and severely tightened down. The result is a painful and disagreeable experience to the patient. The second fault is that the distal ends of the blades tend to spread apart; the consequent loss of applied force at that far point is the cause for failure to divide the spur at its lowermost and important level. Unquestionably, this failure to obliterate the spur entirely

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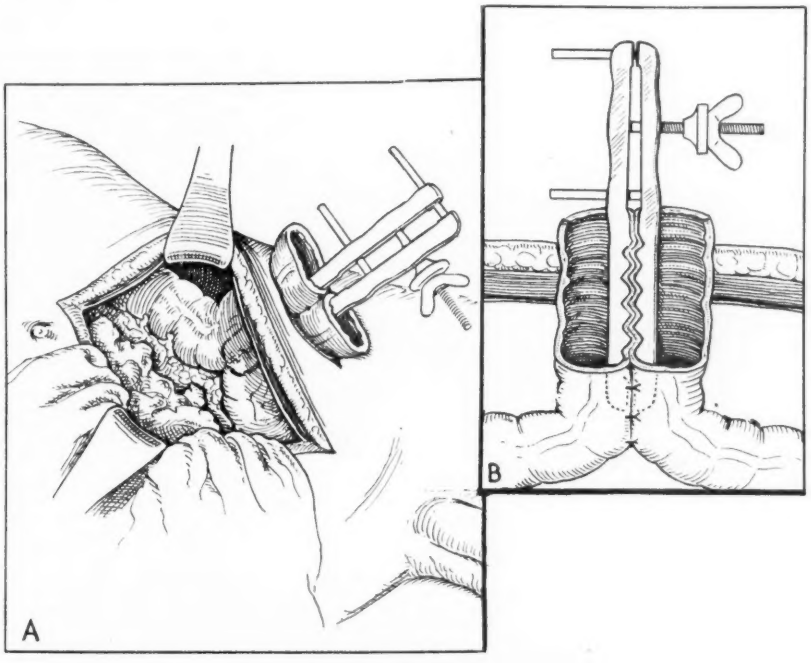
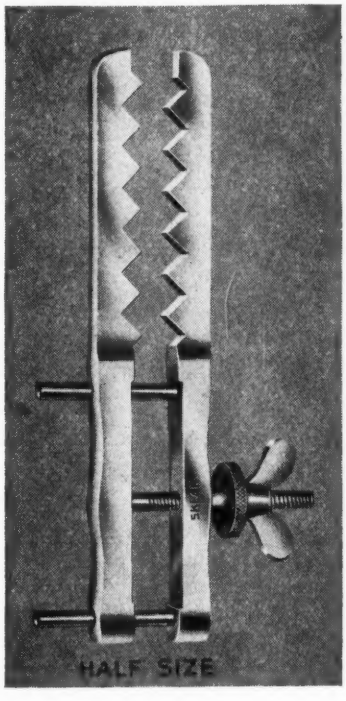
makes it difficult or almost impossible to obtain an immediate and primary closure of the stoma of the colostomy at a later period.

For several years I have employed, with much satisfaction and sufficiently often, a parallel action type of enterotribe, made more helpful and efficient for severence of the intestinal spur by certain changes in the design of the biting surfaces. Both blades are provided with large, evenly spaced saw teeth which





C.

Fig. 1.—*A*, Showing the double-barreled colostomy and its relative position to the abdominal wall with spur clamp in position. *B*, Schematic cutout drawing showing the saw-tooth clamp applied to the double-walled partition of colostomy. *C* Photograph of clamp.

interdigitate with each other. Any slight pressure of the jaws presses and fixes the intestinal septum barrier at multiple points holding it firmly without slipping (Fig. 1 *A* and *B*). Continued pressure stretches segments of the gut over the corrugated surfaces of the blades, thus permitting a quicker division of the septum as the coaptating force is slowly applied. Since each angular digit member of the bite wedges firmly into a counternotch of its opposite companion, it forms a firm multilocking unit which does not allow any appreciable side slipping or end spread of the clamp.

It is helpful, before inserting the open clamp into the two barrels of the colostomy, to dilate those cylinders slightly with a gloved finger which has been coated with any ordinary emollient.

The instrument* as pictured (Fig. 1 *C*) is of stainless steel, with an over-all length of five and three-fourth inches; its crushing blades are three inches in length; the width of the blades one-fourth inch.

CLOSURE OF DUODENAL FISTULA

A New Technique

Major W. H. Snyder, Jr., Lieutenant Colonel C. J. Berne, Captain H. I. Ridell, and Captain E. L. Turner, Medical Corps, Army of the United States

On the afternoon of Jan. 7, 1945, a 29-year-old American soldier was flown from the forward area to our Evacuation Hospital in northern Burma. Two rifle bullets fired at close range had entered the anterior abdominal wall just to the left of the umbilicus and made their exit just to the right of the spinal column avulsing the posterior abdominal wall (Fig. 1) and lower chest, leaving a large ten-inch gaping wound through which blood was pouring from a ruptured kidney and torn renal pedicle. The injury had occurred one and one-half hours before entry. The patient was in profound shock from trauma and hemorrhage.

Blood and plasma were given and in less than one hour after entry, under ether anesthesia, the wound in the lateral wall was extended medially (Fig. 2) by a transverse incision. The adrenal gland and the upper two-thirds of the right kidney were pulpified. They were removed and the kidney pedicle ligated. A three-inch section of the ascending colon had been avulsed by the bullets. The remaining portion of the ascending colon and the hepatic flexure were mobilized and a double-barreled colostomy formed (Fig. 2). The colonic mesentery was used to fill the gap in the lateral abdominal wall. There was a jagged hole in the right lobe of the liver the size of two clenched fists. This was débrided and packed of necessity to stop the hemorrhage. The tenth, eleventh, and twelfth ribs had been shattered and the diaphragm was torn, producing a sucking wound of the chest. This was repaired by suturing the diaphragm to the lateral chest wall. The right portion of the abdominal cavity and the entire wound was contaminated by fecal material from the severed colon. Further

*The instrument is made by the Sklar Manufacturing Company, Long Island City, N. Y.

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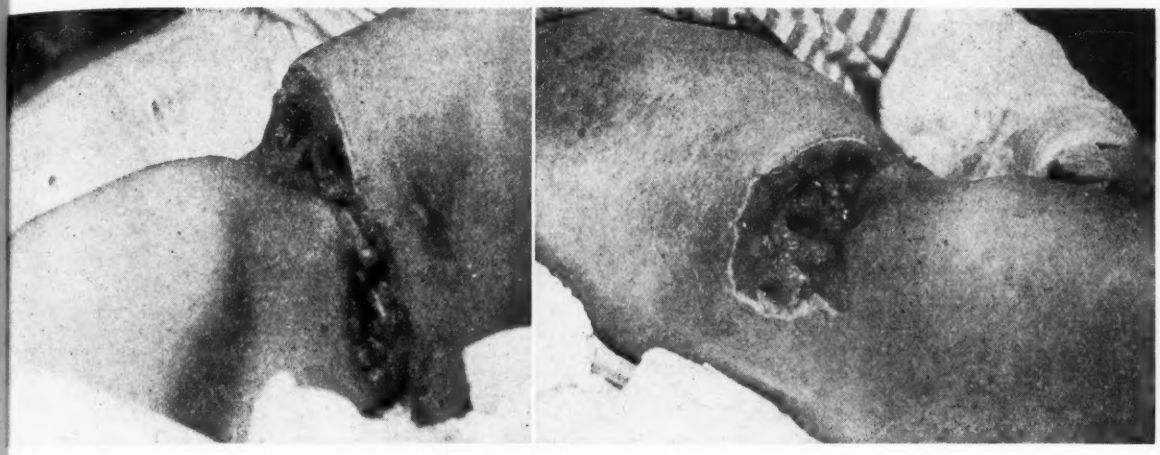

Fig. 1.—Two bullets entered the anterior portion of the abdomen at close range. This shows the extensive posterior gaping wound shortly after débridement.

Fig. 2.—The wound consisted of nearly a hemisection of the body at the level of the first lumbar vertebra.

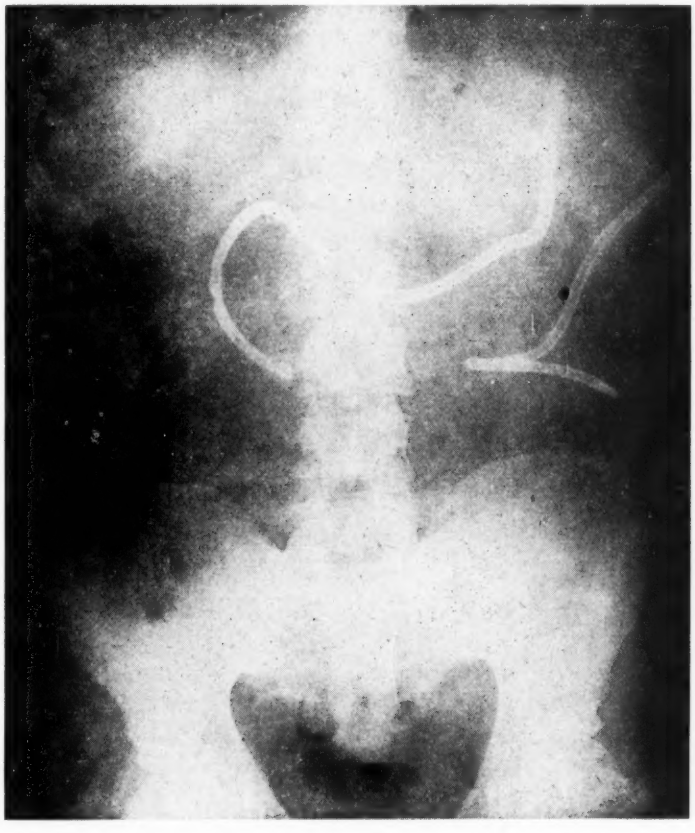

Fig. 3.—The tube on the right passes through a gastrostomy opening into the duodenum and was used for suction. The tube on the left passes into the duodenum and was used for feeding.

abdominal exploration revealed no pathology. The second portion of the duodenum had been exposed by the passage of the bullets, but no gross damage to the wall was visualized.

During the first few days the patient's condition was critical. Constant gastric suction was instituted. Fluid balance was maintained by the intravenous route (Fig. 8) and 200,000 units of penicillin per day were given intramuscularly for five days. On the eleventh day after the original surgery a

duodenal fistula developed. A Witzel jejunostomy was performed and a second tube was directed through a gastrostomy opening into the duodenum for constant suction and salvage of the duodenal fluid (Fig. 3). A second jejunostomy was necessary on the twenty-third day because the previous tube had accidentally become dislodged. On the twenty-fourth day it was possible to insert

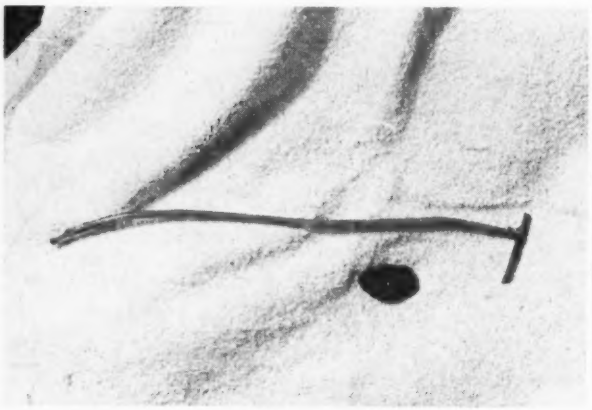

Fig. 4.

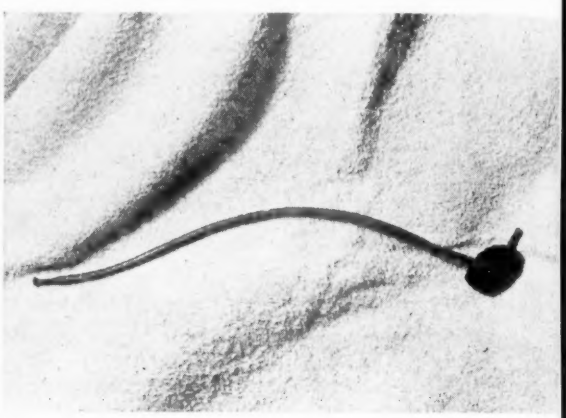

Fig. 5.

Fig. 4.—T tube with elliptical piece of rubber inner tubing. A small hole in the center of the elliptical piece of inner tubing allows the long arm of the T tube to be passed through this opening.

Fig. 5.—T tube and elliptical piece of rubber tubing ready for insertion into the fistula.

Fig. 6.—T tube and elliptical piece of rubber tubing in place in the duodenum exposed in the depths of the wound.

a T tube through the fistulous opening in the duodenum and, with the use of an elliptical piece of rubber inner tubing (Figs. 4 and 5), to form a nearly tight closure. Subsequent to this, normal feedings were possible. The wound was filling in satisfactorily, but lower partial thoracoplasty may be advisable to fill the defect in the lateral wall. It may be possible to effect final closure of the duodenal fistula by simple suture after reaction in the duodenal wall has entirely subsided.

DISCUSSION

Rapid transportation of the patient to the Evacuation Hospital by air, the availability of almost complete laboratory facilities, equipment, and drugs, the application of physiologic principles, early surgery, and good nursing care made it possible for us to evacuate this man in good condition to the General Hospital five weeks after surgery.

The combination of difficulties which were encountered in this case may not be duplicated frequently and yet the same general problems in postoperative management are present in many battle injuries. The physiologic principles and technical devices used in this case will be described with the hope that this information may be helpful to others.

Salt Balance (Fig. 7).—The recent work of Coller and associates[1] on salt intolerance seemed especially applicable in this case, as our patient had only one kidney and one adrenal gland following a right nephrectomy. During the first eight days, while the patient was on constant gastric suction and taking nothing by mouth, the total intake of saline was only 3,000 c.c. Until the recent emphasis on salt intolerance we would have considered this amount entirely inadequate[8] and yet in view of the satisfactory blood chlorides, blood CO_2 (Table I),

TABLE I. LABORATORY FINDINGS

DAYS	2	5	8	12	16	19	23	27
Sp. gr. blood	1.0605	1.057	1.0485	1.059	1.057	1.056	1.061	1.052
Sp. gr. plasma	1.028	1.030	1.0	1.0335	1.031	1.031	1.032	1.027
Hematocrit	47.5	40.5	24		40	38	45	35.5
Hemoglobin (Gm.)	14.5	13.7	9.9	13.5	13.5	12.9	15.2	12
		12.5	9.5					
R.B.C.	4.84	4.17	2.76	3.91	4.39	3.38	5.17	4.34
								3.62
W.B.C.	24.800	16.300	19.750	12.900	9.700	8.850		8.050
Blood chloride (mg.)			393	505	528	545	470	561
				482				
Blood CO_2 (vol. %)			62	72	73	46		52
N.P.N. (mg. %)		102	44		59	84	70	40
Plasma protein (Gm.)	7.2	7.9	7.3	9.1	8.2	8.2	8.6	6.8
Urine albumin		1+	1+	1+	1+	1+	1+	Neg.
Urine sp. gr.			1.018	1.018	1.015	1.019	1.022	1.016
Urine chloride (mg. per liter)			3-4	0-1	0-1	2	0-1	6-7
								4

adequate urinary output (Fig. 8), and in view of the persistent albumin in the urine, high nonprotein nitrogen, reversed albumin globulin ratio, and low salt output in the urine[3] we cannot but feel that this case adds some support to Coller's new concept of guarded control of salt intake.

From a study of Fig. 7 it appears that a fair quantity of salt was administered during the first eleven days. However, we wish to re-emphasize that all of this intake of salt came from blood and plasma (100 c.c. of plasma equals 0.6 Gm. of salt, and 100 c.c. of blood equals 0.5 Gm. of salt), with the exception of a total of only 3,000 c.c. of saline given in the first eight days. Unless the blood and plasma source of salt is recognized many patients with war injuries will postoperatively be overloaded with salt. Edema of the intestines and fluid collection in the abdomen can be easily mistaken for peritonitis.

After the development of the duodenal fistula the salt intake was greatly increased and was administered both through the jejunostomy and intravenously. Most of the fluids escaping from the duodenal fistula were returned through the jejunostomy so that salt which otherwise would have been lost in this way was utilized. Fig. 7 shows only the additional salt administered.

The fluid balance, which is related to the salt balance, is shown in Fig. 8. The tremendous amounts of fluid which were necessary to maintain a balance were in the main given through the jejunostomy after the eleventh day. In addition blood, plasma, and saline and glucose were given intravenously. On

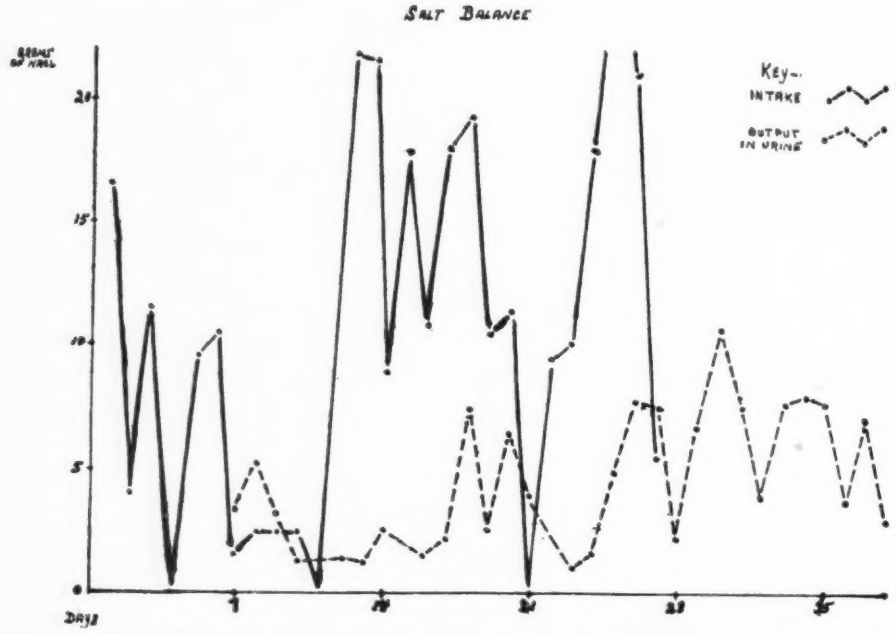

Fig. 7.—In calculating the intake of salt we considered each 100 c.c. of plasma equal to .6 Gm. of NaCl, each 100 c.c. of blood equal to .5 Gm. of NaCl, and each 100 c.c. of normal saline solution equal to .9 Gm. of NaCl; the output in the urine was determined according to a recent directive.[2]

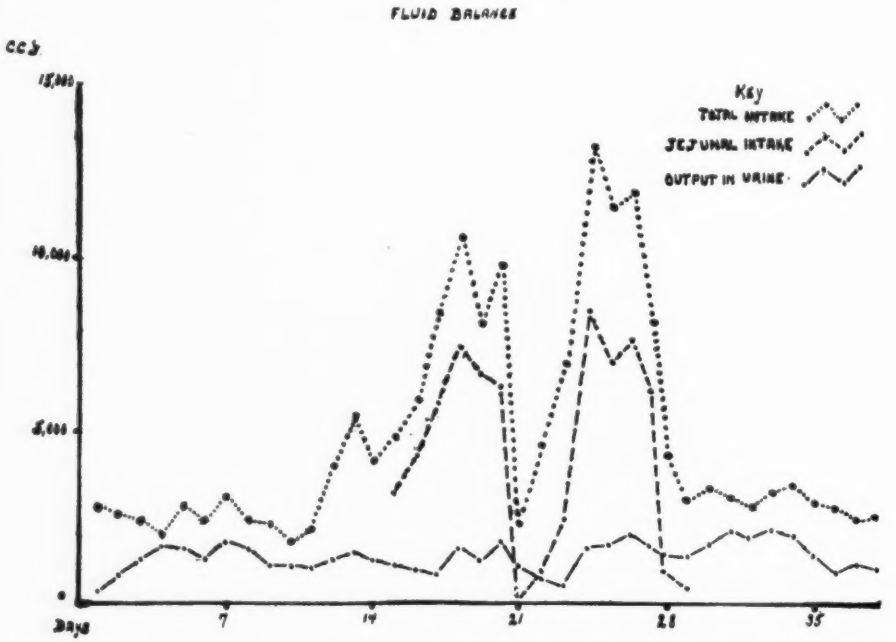

Fig. 8.—Total intake includes amount given by vein, mouth, and jejunum. Jejunal intake equals the total amount given through the jejunostomy.

some days the fluid intake through the jejunostomy reached nearly 9,000 c.c. of which nearly 5,000 c.c. were composed of bile, pancreatic and intestinal juices. We feel sure that the collection and return of this fluid through the jejunostomy was an important factor in this patient's recovery.

Protein Balance.—During the first eight days all protein (Fig. 9) was given intravenously in the form of blood and plasma.[4] Subsequently, some protein was given by mouth. During this period while the loss through the duodenal fistula was great, the protein taken by mouth and excreted through the fistula was returned through the jejunostomy. In addition, a considerable amount of protein was administered in the form of an egg and milk mixture through the jejunostomy. It is obvious from Fig. 9 that the protein intake was not adequate, but attempts to increase the amount were thwarted by the development of intestinal disturbances. By the twenty-eighth postoperative day, the drainage from the duodenal fistula was controlled and subsequently all protein was administered by mouth. Supplementary intravenous administrations of Amigen[5] would certainly have been desirable, but this was not available.

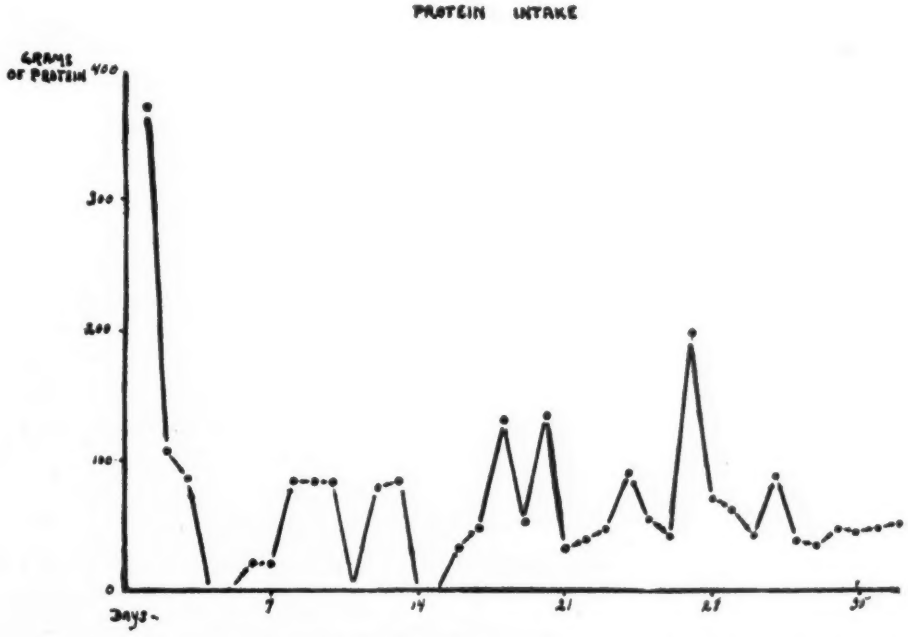

Fig. 9.—The amount of protein given this patient was calculated from the ingredients administered, that is, 100 c.c. of plasma equals 7 Gm. of protein, 100 c.c. of blood equals 18 Gm. of protein,[4] 100 Gm. of powered milk equals 27 Gm. of protein; protein content of diet also added.

Collection of Duodenal Contents.—On the eleventh postoperative day bile and duodenal content appeared in the depths of the wound. Although no gross damage to the duodenum was evident at the time of the original surgery, the wall of the second portion had been traumatized by the bullet and a break in its continuity developed. For the first few days the loss of duodenal contents was minimal. On the thirteenth day a major duodenal fistula was present and the effects of this complication were evident in the patient's general condition. A jejunostomy was, therefore, performed for feeding purposes. The position of the gunshot wound on the posterior lateral wall made aspiration of the leaking duodenal fluids technically almost impossible. Repeated attempts[6] to pass a Miller-Abbott tube was unsuccessful. In order to salvage as much of the duodenal contents as possible, a tube was inserted through a gastrostomy opening and directed into the duodenum (Fig. 3). Continuous aspiration was maintained by means of this tube. This procedure was fairly successful, but there was still considerable fluid lost. The duodenal opening had enlarged and could now be easily seen in the depths of the wound. Attempted suture was unsuccess-

ful due to the edema of the surrounding duodenal wall. Finally a common duct T tube was inserted through the fistula and suction applied. Even though it was possible to return most of the duodenal drainage by means of the jejunostomy and in spite of additional forced jejunostomy feedings, the patient did not make satisfactory progress. After many other unsuccessful attempts to close the duodenal fistula an elliptical piece of rubber was fashioned from an old inner tube (Figs. 4 and 5) and a T tube threaded through a hole in its center. This assembly was then inserted through the fistula (Fig. 6). By tension on the T tube, pressure was made against the inner wall of the duodenum by the elliptical piece of rubber inner tubing, resulting in a nearly watertight closure of the fistula. This type of internal valve closure with a T tube and elliptical strip of rubber tubing has served its purpose. At least it has tided our patient over a crucial stage and the device may be applicable as a temporary measure in the closure of other duodenal fistulas, such as those occurring in accidental posterior wounds following nephrectomy.

SUMMARY

1. In large avulsing wounds of the posterior lateral abdominal wall the utilization of the mesentery of the colon may provide a satisfactory reconstruction.

2. With the loss of one kidney and adrenal gland plus severe abdominal trauma, limitations of salt intake according to Coller's new concept is apparently beneficial.

3. The temporary closure of a wound in the posterior lateral wall of the second portion of the duodenum may be effected by the use of a T tube and elliptical piece of rubber inner tubing.

4. The United States Army has provided facilities for extensive laboratory studies even in remote areas of Burma.

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A METHOD OF IMPLANTING THE PANCREATIC DUCT INTO THE JEJUNUM IN THE WHIPPLE OPERATION FOR CARCINOMA OF THE PANCREAS

Case Report

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(From the Department of Surgery, University of Minnesota Hospitals)

A UNANIMITY of opinion does not yet exist concerning the necessity of the external secretion of the pancreas for the maintenance of a completely healthy nutritional state. Even a cursory appraisal of case reports, in which the radical operation for cure of carcinoma of the head of the pancreas has been performed without attempting to preserve this secretion, suggests that the nutritional effects may be quite variable. With some,[1-3] a very nearly normal existence is enjoyed; at other times, the patient's state is clearly an unsatisfactory one, unless a substitution therapy of lecithin, choline, or raw pancreas is provided to correct steatorrhea and other evidences of disturbed fat metabolism. To date, which case will tolerate deprivation of this juice has been an impossible prediction and, hence, presents a major therapeutic obstacle to all who favor ignoring this problem. Also, any procedure capable of reducing the incidence of external pancreatic fistula, a not sufficiently infrequent complication after ligation of the duct, should warrant additional consideration for itself. Finally, if the anastomotic method is simple, requires no special paraphernalia, and appears to yield consistent results, it would seem to merit trial and scrutiny by others at work in the field on this problem. For these reasons, the method of pancreatico-enterostomy devised and tried in the experimental laboratory in 1941 is reported here. At that time, I was studying intestinal absorption from Thiry loops of the duodenum, which required a segment as completely free as possible of biliary and pancreatic secretions. These experiments were designed for a long-time study. To insure, therefore, the best nutritional status, the biliary duct and main* pancreatic ducts were transplanted usually to the upper jejunum. Following this procedure, six animals remained in excellent health without steatorrhea or other evidence of abnormal fat or protein metabolism, while maintained on a fare of hospital scraps, dog biscuits, and occasional supplements of horse meat. When sacrificed at from six to ten months after surgery, the pancreas in all cases was a normal pale yellow-pink color and possessed a pliable soft consistency. In several instances, a short patulous segment of duct at the site of transplantation could be identified. Neither the liver nor the pancreas was sectioned but appeared grossly normal. Because of its apparent success, this method was applied to a patient on Aug. 5, 1943, during the course of a resection for carcinoma of the head of the pancreas.

CASE REPORT

A. W. (University Hospital No. 733594), a white man aged 70 years, first noticed the onset of painless jaundice about two or three weeks prior to his initial hospital visit on

The researches upon which this presentation is based were supported by a grant from the Graduate School of the University of Minnesota.

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*Any additional ducts were divided, ligated, and separated from the duodenal wall by a slip of omentum.

July 7, 1943. It had increased steadily in intensity during this interval, and had not been associated with any pruritis or physical incapacity. Stools had been clay colored, the urine dark for about two weeks. When the patient was admitted upon the medical service, the positive physical findings were jaundice with a greenish cast, an enlarged gall bladder, and a reducible, indirect left inguinal hernia. Quantitative analysis of a four-day stool indicated 3 mg. of urobilinogen per day. The total serum bilirubin was 8.7 mg. per cent with 6.5 mg. per cent appearing in the first minute. X-ray examination of the stomach and duodenum was reported to be normal. The diagnosis was carcinomatous biliary obstruction probably due to carcinoma of the head of the pancreas. The patient insisted upon returning to his home before the operation, was admitted to the surgical service on July 25, 1943, and operated upon Aug. 5, 1943. During this interval he was prepared with a high protein, carbohydrate, caloric, low-fat diet, fortified with liberal quantities of thiamine, cevitamic acid, and vitamin K. Anesthesia was secured with a nupercaine spinal and endotracheal inhalation of cyclopropane. A partial gastric resection, complete duodenectomy, resection of the head of the pancreas, resection of proximal 16 cm. of the jejunum, cholecystojejunostomy, catheter choledochostomy, catheter pancreaticojejunostomy, and gastrojejunostomy were performed. At the time of the exploration through a transverse incision, a mass involving the distal portion of the common bile duct and head of the pancreas was felt and deemed to be carcinomatous. The greater and lesser curvatures of the stomach were devascularized and it was divided approximately in the mid-portion. The common duct was then transected and the duodenum freed from its avascular attachments to the inferior vena cava and transverse mesocolon as well as from the blood supply through the mesenteric vessels. The pancreas was sectioned caudad to the neck, isolating the main pancreatic duct with preservation of a short extra glandular segment. Pursuance of the dissection in the vicinity of the splenic, portal, and superior mesenteric vessels ultimately allowed removal of the specimen in a single mass. The fundus of the gallbladder was then anastomosed to the end of the jejunum, a catheter choledochostomy was made, and a terminolateral gastrojejunostomy was effected about 45 cm. from the proximal cut end of the small bowel.* About midway between these two points, the pancreatic duct was implanted. Two sutures of fine silk were so placed as to hold patulous this thin-walled structure. An 8 cm. piece of No. 12 size, two-holed catheter was then inserted for a distance of from 1 to 2 cm. This was accomplished by essentially the same plan as had been employed during pancreatic duct implantations carried out in the experimental laboratory. In Fig. 1† illustrations of the operative procedure detail the operative steps in a very satisfactory manner. The procedure is as follows.

DESCRIPTION OF METHOD FOR IMPLANTING PANCREATIC DUCT

A two-holed catheter is selected, which is somewhat larger in diameter than the conduit to be intubated. An 8 cm. segment of this is stretched over an obturator (a Keith skin needle serves very well) impaled at a point on the catheter wall slightly eccentric to the tip and away from the lateral opening in the catheter. With increasing elongation of the catheter over this rigid probe, there is an appreciable decrease in its transverse diameter. This condition is then maintained by clamping all structures firmly with a sturdy hemostat at some distance from the tip. An oblique section is now cut from the tube, care being taken to place this line of excision distal to the tented wall of the catheter. The stylet bearing this prepared catheter is then slipped a short distance into the duct, facilitated by slight traction on the previously placed guy sutures. Release of the hemostat then allows the catheter to resume its originally greater diameter, thus snugly filling the cannulated duct. To insure this coaptation between catheter and duct, a fine catgut or silk ligature can be pulled down gently onto the duct wall in its extra glandular portion. Usually, the seal is satisfactory without this, and pancreatic secretions drip freely in a short while from the free end of the catheter. With fine interrupted silk sutures the serosa of the jujunum is then approximated to the fibrous elements of the pancreatic capsule along its posterior, superior, and inferior margins. A fine puncture is made through all coats of the jejunum at the site selected from the anastomoses. This is effected easily by the pointed end of a Keith or some other cutting edge needle. No formal incision is necessary. The firm substance of the catheter readily dilates the merest point of entrance through the tough submucosal coat. Such a close fit then assures a nice apposition between the several layers of

*The operative plan is essentially that described by Dennis.[4]

†Drawn by Miss Daisy Stilwell.

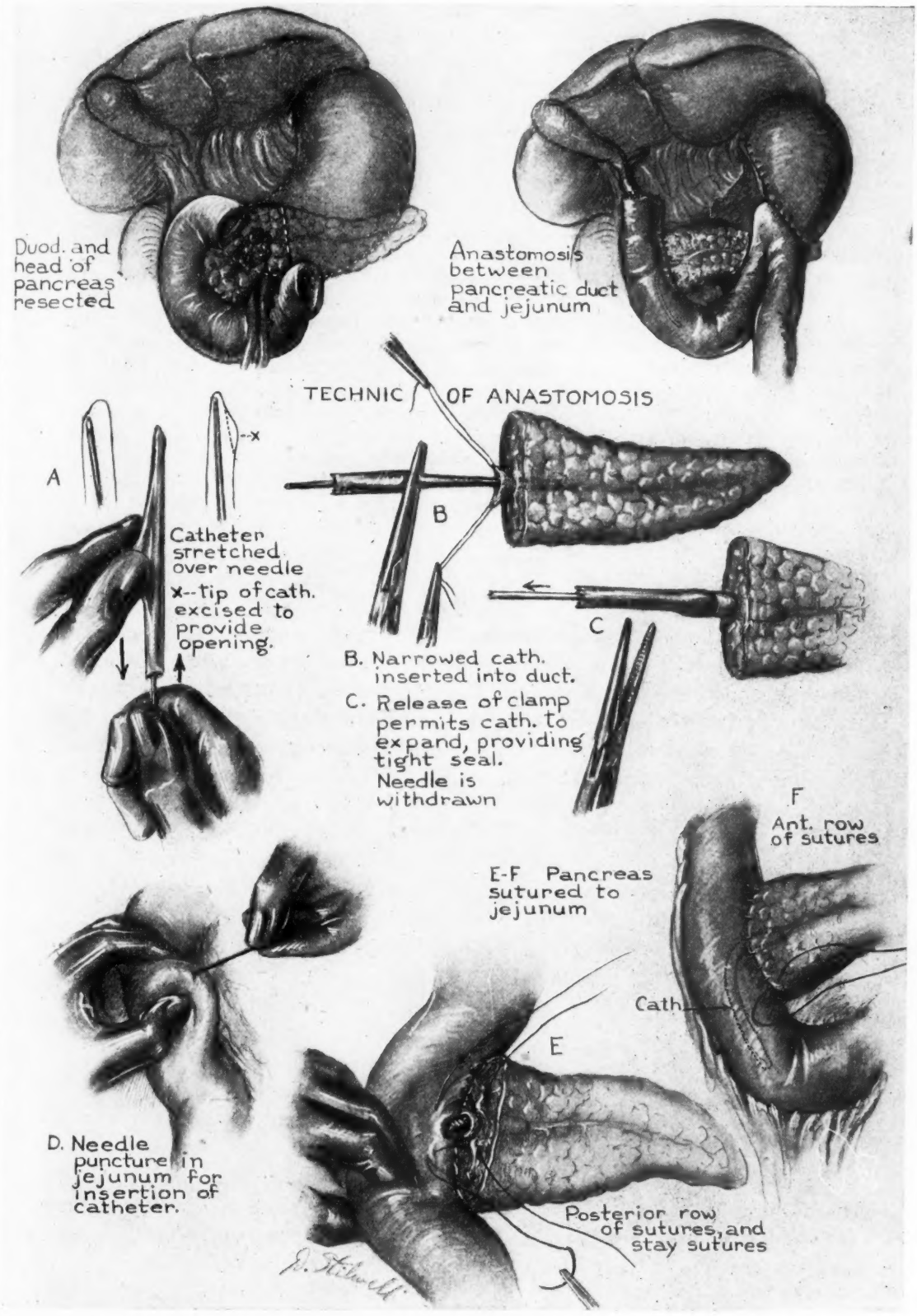
Duod. and head of pancreas resected
Anastomosis between pancreatic duct and jejunum
TECHNIC OF ANASTOMOSIS
A
x
Catheter stretched over needle
x--tip of cath. excised to provide opening.
B
C
B. Narrowed cath. inserted into duct.
C. Release of clamp permits cath. to expand, providing tight seal. Needle is withdrawn
F
Ant. row of sutures
E-F Pancreas sutured to jejunum
Cath
E
D. Needle puncture in jejunum for insertion of catheter.
Posterior row of sutures, and stay sutures

Fig. 1.—The two drawings at the top indicate approximately the site involved by malignancy and diagram the visceral configuration in the completed procedure, based on the Dennis[4] plan of operation for carcinoma of the head of the pancreas. The technique of implanting the pancreatic duct into the jejunum is shown in sketches *A* to *F*.

the enteric wall and the pancreatic duct. Two fine silk stitches are placed between the connective tissue adjacent to the duct and the bowel wall next to the puncture site. Tying these ligatures as the catheter and duct are threaded through the small aperture into the gut lumen firmly approximates the pancreas to the bowel and reduces any tendency for the duct to escape from its intramural and intraluminal position. The serosa of the jejunum is then tacked with fine silk sutures to the capsule of the pancreas about the remainder of its periphery, namely, the anterior aspect.

Drains were placed down to this area and the site of the catheter choledochostomy, and were brought out through separately placed wounds. The abdomen was closed in layers with fine silk sutures. The patient was slightly febrile until the removal of the indwelling duodenal tube on the sixth day. No drainage of moment occurred and therefore the drains were removed at about this time also. The pancreatic catheter was passed some time after the tenth postoperative day. There was a gradual decline in the patient's jaundice following a temporary increase postoperatively. The stools, although virtually bile-free through failure of the cholecystojejunostomy to function properly, were never foamy or diarrheic, nor did they contain excess fat or protein. No studies were made of the intestinal contents for tryptic activity. Recovery was protracted several weeks by bouts of gastric retention and delayed emptying, which had virtually disappeared when a barium study was secured on Sept. 7, 1943. The patient returned for a change of the choledochostomy tube on Oct. 1, 1943, and stated bile was now present in stools when the tube was clamped. His health was fair at the time with some gain in weight since his discharge. There was no diarrhea, and he was constipated if anything. His health began to fail in January, 1944, and he died shortly thereafter of what clinically seemed to be a recurrence, since no autopsy was secured.

DISCUSSION

The convalescence was unnecessarily complicated and prolonged; he was not discharged until the thirty-nine postoperative day because of two technical blunders. A cholecysto-enterostomy was made instead of the more satisfactory end-to-end anastomosis between the common duct and the small bowel. Whipple[5] has called attention to the hazard and undesirability of the former procedure. Fortunately, a catheter had been placed in the end of the common duct as a safety vent in case the cholecystojejunostomy failed to function adequately. This one did not for many weeks; during this period the bile drained to the exterior chiefly via the catheter choledochostomy. A choledochojejunostomy alone, or protected by a catheter placed into the common duct through the cystic duct after removal of the galbladder, it should be emphasized, is the procedure of choice. The second technical error was related to threading the jejunum for the gastric anastomosis up the bed occupied by the duodenum, and, hence, behind the superior mesenteric vessels. An antecolic positioning of the loop would have avoided the troublesome episode of gastric retention and vomiting. By buttressing the cut end of the pancreas with the peritoneal coat of the bowel wall, any oozing of pancreatic secretion from the cut surface is somewhat limited. However, diversion of the bulk of these strongly proteolytic enzymes to a site several centimeters removed where they may occasion no real damage, probably is the major factor in averting a pancreatic fistula. My colleague, Clarence Dennis, of the surgical staff of the University of Minnesota Hospitals, since has employed essentially this plan for implanting the pancreatic duct in three additional cases. There has been no instance of pancreatic fistula.

SUMMARY

1. A simple effective method for implanting the pancreatic duct is described.

2. The case record of a patient upon whom this method was used is reported in detail. Three additional instances of its utilization are cited.

3. Some of the technical features in the operation of radical resection of the head of the pancreas are discussed.

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SUBTOTAL AND PALLIATIVE GASTRECTOMY FOR CHRONIC GASTRIC ULCER

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THE pathologic findings in acute and chronic gastric or duodenal ulcer are essentially identical. Both have a definite life cycle characterized by periods of exacerbations and remissions. Clinically, the symptomatology produced is often so similar that a differential diagnosis cannot be made. As a rule, both respond to adequate medical treatment. Gastroduodenal ulceration becomes a surgical problem only when certain complications arise which do not respond to medical therapy. The indications for operative intervention have been fairly well crystallized. The ulcer becomes an urgent surgical problem when an acute perforation occurs and in very exceptional cases when an exsanguinating hemorrhage persists. The chronic ulcer ultimately concerns the surgeon when the symptoms become refractory to medical treatment, when hemorrhages are recurrent, and when a pyloric obstruction becomes intractable to conservative measures. However, an ulcerating lesion in the stomach presents an additional problem which does not apply to duodenal ulcer—the possibility that it may be malignant.

It is this differentiation between a benign and carcinomatous ulcer which may offer insurmountable difficulties even when the best diagnostic facilities are available. Klingenstein,[1] in 1936, presented before the New York Surgical Society a series of 165 cases of chronic gastric ulcer in which operation was done between 1925 and 1935. In 20 per cent of these cases, a preoperative diagnosis of carcinoma had been made by the roentgenologist, and in 12 per cent an ulcer, previously thought to be benign, was proved to be malignant at operation. While it is true that a benign ulcer rarely undergoes malignant degeneration, carcinoma cells were found in two of a series of 141 pathologic examinations of chronic gastric ulcer made by Klein.[2] Recently, Yarnis and Colp[3] reported three cases of benign ulcer in which an unsuspected independent gastric carcinoma existed simultaneously. Furthermore, experience has shown that the temporary disappearance of an ulcer niche, following a course of medical therapy, is not positive proof that a carcinoma does not exist. These facts illustrate the uncertainties in making an accurate diagnosis of any gastric

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lesion, and if they were constantly borne in mind, there undoubtedly would be less hesitancy on the part of the medical profession in subjecting a patient with a chronic ulcer niche to radical surgery.

This communication deals with a review of forty-two consecutive patients with chronic gastric ulcer who were admitted to the surgical ward service of the Mount Sinai Hospital during a six-year period from July 1, 1937, to June 30, 1943.

HISTORY

This series was composed of four women and thirty-eight men. Thirty-four patients were between the ages of 40 and 60 years; the youngest patient was 21 years, the oldest was 64. The duration of the disease varied from several months to forty years, and was characterized by acute episodes of varying intensity, usually responding to some type of medical therapy. Ten patients had one or more recurrent gastric hemorrhages. Two experienced previous gastric perforations which had been sutured several years before their present admissions. Ten patients had been hospitalized at one time or another for the medical treatment of an ulcer. All patients with one exception complained of epigastric pain which had hitherto been intermittent and was now becoming more persistent and severe. Occasionally a history of back pain suggested the possibility that the ulcer had penetrated the pancreas. In some, nausea, vomiting, and anorexia, which had been only occasional, became more pronounced, and many patients volunteered the information that the vomitus often contained food eaten the previous day. Loss of weight had occurred in one-half the patients.

Patients were admitted to the surgical service only when the pain was becoming more severe despite adequate treatment, when an intractable pyloric stenosis was evident, when hemorrhages had become recurrent, and when the presence of a carcinoma was suspected.

PHYSICAL EXAMINATION AND LABORATORY DATA

Physical examination in many instances disclosed evidences of recent weight loss and dehydration. Epigastric tenderness was present in a few patients. As a rule the Rehfuss test meal disclosed an increase above the normal values in the free and total acidity but the reports of gastric analyses were interpreted with circumspection. It should be universally known by the present time that the findings of a hyperacidity in the presence of an ulcerating lesion do not rule out the possibility of a carcinoma, and that a benign ulcer may exist in the presence of a low free hydrochloric acid. For example, in a series of 140 patients studied by one of us (R. C.), the presence of a gastric carcinoma was proved by operation, yet the test meals in over one-half showed free hydrochloric acid values ranging from 20 to 60 millimoles per liter and combined acidity of from 40 to 113 millimoles per liter. In fifty patients the gastric analyses disclosed the absence of free hydrochloric acid although the combined acidity varied from 10 to 80 millimoles per liter. The entire question of the pre- and postoperative acidities in our material is being studied and will be presented in detail elsewhere. An absolute achlorhydria was present in only twelve cases. In the present series of forty-two proved benign ulcers, twenty-five patients had an elevated acidity and fifteen patients had normal acid figures. In two cases the acid studies had been lost.

The barium meal examination was of inestimable value in the differential diagnosis of benign and malignant lesions of the stomach, for the characteristic x-ray findings would often indicate the presence of a benign gastric ulcer or

point unmistakably to a malignant one. In this series of forty-two benign gastric ulcers, the roentgenologist reported three cases as highly suggestive of neoplasm. In six cases, an additional deformity of the duodenal bulb was reported and operation revealed either a healed duodenal scar or active ulcer, as well as the gastric lesion. In three cases, in which a duodenal deformity alone was reported, a gastric ulcer which had been unsuspected was found at operation. The amount of barium retention revealed by gastric roentgenograms is often misleading. The quantity of residue obtained by aspiration through a stomach tube after a twelve-hour fast is a more reliable index of gastric dilatation secondary to pylorospasm or organic obstruction.

Borderline cases in which a definite diagnosis cannot be made are often clarified by gastroscopy, which was performed on twenty-seven patients. In one patient the examination was unsatisfactory, and in four patients the gastric ulcer could not be visualized gastroscopically although it was demonstrated roentgenographically. In the twenty-two other cases, the gastroscopist visualized definite gastric ulcerations, five of which he pronounced malignant, but which were subsequently proved benign. However, it must be realized that certain areas of the stomach cannot be seen with the Schindler gastroscope and that the value of this examination is partly dependent upon the skill of the gastroscopist. Both roentgenologic and gastroscopic examinations are indispensable in the diagnosis of gastric lesions; but even the use of both methods will not eliminate entirely the possibilities of errors in diagnosis.

A complete blood count and chemical examination of the blood (urea, chlorides, CO_2 combining power, and plasma proteins) were always made. Anemia, hypoproteinemia, and alkalosis were not infrequently encountered in those patients who had been vomiting or bleeding prior to admission. For example, J. K. (No. 457919) entered the hospital after many weeks of pain, vomiting, and tarry stools. The hemoglobin was 120 per cent, the plasma proteins 5.9 Gm. per cent, the blood urea 35 mg. per cent, and the CO_2 combining power 84.5 vol. per cent, evidences of recent bleeding, dehydration, and alkalosis.

PREOPERATIVE PREPARATION

Many of these ward patients, when admitted, were in poor general condition. The systemic effects of the intractable pain, inadequate nutrition, vomiting, and hemorrhage were reflected in loss of weight, dehydration, anemia, and certain chemical imbalances, all of which needed correction prior to operation.

All patients were given an initial period of complete bed rest. Pain was controlled with mild sedatives, aluminum hydroxide, atropine, the frequent feedings of bland foods, and occasionally the milk and amphojel drip as advocated by Winkelstein, Cornell, and Hollander.[4] Adequate hydration was assured by the daily administration of 1,500 c.c. of saline solution and glucose. If, because of pyloric obstruction, vomiting had been a prominent symptom, the amount of daily intravenous fluids was increased to 4,000 c.c. and a gastric lavage with hot saline solution was performed twice daily through a large gastric tube. This latter procedure often allayed the spasm or reduced the inflammatory reaction about an edematous pylorus to such a degree that gastroduodenal continuity was restored, with the subsequent cessation of vomiting, diminution of pain, and a marked improvement in the general condition of the patient. Adequate vitamins were administered. Repeated transfusions of whole blood were given to anemic patients until the hemoglobin was elevated to 80 per cent. Whenever possible, regardless of age, treatment is conservative for the majority of the patients with massive hemorrhage, operation being deferred until they

have fully recuperated from the systemic effects of their blood loss. Only one patient was operated upon during acute hemorrhage. This was done because it was believed that the patient was suffering from a bleeding carcinoma of the stomach, not a bleeding ulcer.

CASE 1 (No. 440605).—W. H., a 60-year-old man, was admitted to the Mount Sinai Hospital, May 18, 1939, complaining of epigastric pain of one year's duration. During this time the pain had become increasingly severe, and recently had been accompanied by nausea, vomiting, a loss of fifteen pounds, and attacks of weakness. For four weeks the patient had had tarry stools daily. The past history was noncontributory except for the fact that the patient had been a moderately heavy drinker.

Physical examination disclosed a chronically ill, very pale, elderly man. There was moderate peripheral sclerosis; the blood pressure was 100 systolic and 70 diastolic. There was moderate epigastric tenderness.

The hemoglobin was 27 per cent, the red blood count was 1,590,000, and white blood count 15,000. The blood urea was 11 mg. per cent, blood sugar 105 mg. per cent, CO_2 combining power 53.8 vol. per cent, total protein 4.7 Gm. per cent. The urine was negative. The stools were tarry and were markedly positive to the guaiac test for blood. The electrocardiogram was normal. The test meal revealed free acid 50 millimoles, combined 66 millimoles. X-ray disclosed the presence of a penetrating ulcer at the re-entrant angle of the stomach. Gastroscopy revealed a deep lesser curvature ulcer which was very suggestive of carcinoma.

The patient was put at complete bed rest. He was fed the Muelengracht diet and was given adequate vitamins and sedatives. Repeated transfusions of whole blood were administered until the hemoglobin was elevated to 68 per cent. However, because of the persistence of the pain, the guaiac positive stools, and the gastroscopic appearance of the lesion, it was felt that the patient was suffering from a neoplasm of the stomach, and therefore exploration was indicated despite the recent hemorrhage.

Accordingly, on June 3, 1939, laparotomy was performed under ethylene ether anesthesia. A definite benign gastric ulcer quite adherent to the pancreas was found and a subtotal gastrectomy and posterior terminolateral gastrojejunostomy of the Hofmeister type was performed.

The patient made an uneventful recovery and was discharged on the fifteenth day.

If a high protein diet was ineffective in correcting a hypoproteinemia, plasma and amino acids in adequate amounts were administered parenterally. None of the patients in this series required a preliminary jejunostomy for alimentation. Desoxycorticosterone was used preoperatively in eight patients but as no definite benefits were noted in these or in other cases its use was discontinued. The sulfonamides were not used preoperatively.

ANESTHESIA AND OPERATION

Almost every type and combination of anesthesia have been used. Twenty-five of the patients received general inhalation anesthetics and seventeen were given continuous spinal anesthesia. At present, continuous spinal anesthesia combined with sodium pentothal intravenously is considered the method of choice as it provided the best relaxation and exposure, with a minimal amount of retraction.

The abdomen was routinely explored through a median epigastric incision extending from the ensiform cartilage to the umbilicus. The pathologic findings encountered were varied in so far as the location, extent, and depth of the lesions were concerned. For conveniences of description, the location of the ulcers may be divided into those which occupy the pyloric area (which was found only once), those situated in the antrum, those located at or near the re-entrant angle on the posterior wall of the stomach, and those in the cardia. Many of the posterior wall ulcers were of the penetrating variety and were attached to or had eroded into the pancreas. Ulcerating lesions larger than

2.5 cm. in diameter are not necessarily malignant. This is well illustrated in Case 2.

CASE 2 (No. 499998).—F. B., a 57-year-old man, was first admitted to the Mount Sinai Hospital Jan. 5, 1943, complaining of progressive weakness during the previous six months, and postprandial vomiting for the previous six weeks. He had lost fourteen pounds and had suffered from pronounced anorexia. He had never had any pain or noticed tarry stools.

Physical examination disclosed a pale, emaciated man. The chest was emphysematous. No masses or tenderness was present in the abdomen.

The hemoglobin was 57 per cent. The blood sugar was 80 mg. per cent, urea 12 mg. per cent, CO_2 combining power 60.2 vol. per cent, chlorides 575 mg. per cent, and the proteins 7.5 Gm. per cent. The urine was negative and the stool contained occult blood. The test meal disclosed a free acid of 60 and a combined acid of 80 millimoles. The electrocardiogram was normal. X-ray of the stomach (Fig. 1) revealed a huge ulcer and a large ulcer pocket on the lesser curvature, above the re-entrant angle. Gastroscopy disclosed a large ulcerating lesion involving the entire posterior wall of the corpus of the stomach. The distal edge was just proximal to the angularis, and the proximal edge appeared to be 3 cm. from the cardia. The lesion was thought to be a large ulcerating carcinoma.

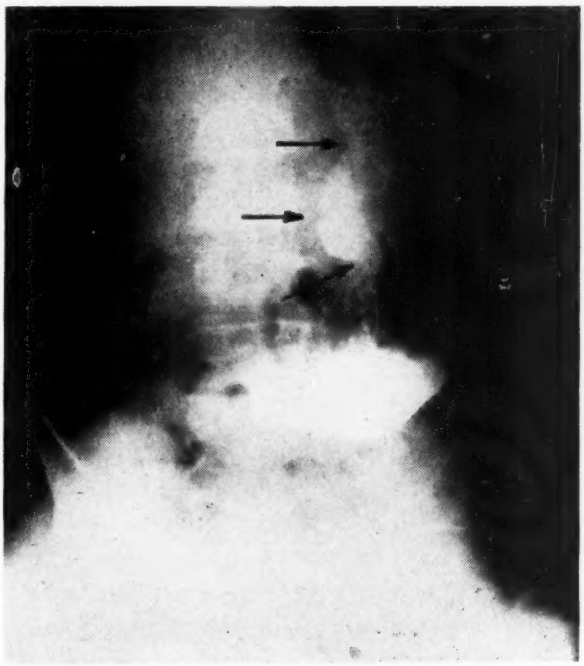

Fig. 1.—Arrows depict enormous extent of ulcer.

The patient was prepared in the usual fashion with transfusions, gastric lavages, vitamins, intravenous fluids, and rest. Exploration was done, Jan. 25, 1943, through the usual midepigastric incision. A large hard mass with an ulcer crater was felt on the posterior wall and lesser curvature of the stomach. It was firmly attached, over a broad area, to the pancreas, which was subsequently found to form the ulcer base. A retrograde gastrectomy was performed. The necrotic surface of the pancreas was not excised, but was covered with sulfanilamide. The area was drained by a rubber dam which was brought out through a right subcostal stab incision. Gastrointestinal continuity was re-established by a typical retrocolic gastrojejunostomy. A complementary jejunostomy for alimentation was performed. The wound was closed with through-and-through sutures.

The pathologic report of the specimen was large chronic peptic ulcer of the stomach, measuring 4.5 by 2 cm.

The patient made an uneventful recovery.

A few penetrating ulcers of the lesser curvature were found which evidently had previously perforated and were sealed off by the liver and in one instance by the gall bladder.

In a few patients in whom a preoperative diagnosis of pyloric obstruction had been made, an ulcer on the lesser curvature of the stomach and a normal pylorus were found at operation. In these cases a reflex pylorospasm or a disturbance of the peristaltic wave must be assumed.

The surgery of chronic gastric ulcer has run the gamut of technical procedures, many of which have now been discarded. Gastroenterostomy with or without local excision has not been found to be an entirely satisfactory procedure. While it is true that gastric acidity was diminished due to the neutralizing effects of the alkaline jejunal regurgitation, the symptoms were rarely permanently relieved and the recurrence of either a gastric ulcer or the formation of the more serious gastrojejunal ulcer has been frequent. Sleeve resections, because of the resultant hourglass deformities leading to physiologic dysfunctions, are no longer done. The operation of choice for chronic gastric ulcer in this clinic is subtotal gastrectomy of the Hofmeister type. This procedure has distinct advantages. It radically removes the pylorus and most of the ulcer-bearing area of the stomach, and if the resected specimen should contain malignant cells, the chances of cure are naturally materially enhanced. In addition, it assures relief of symptoms in practically all cases and freedom from future recurrent ulcerations. A follow-up study of Rehfuss test meals in patients subjected to partial gastrectomy for gastric ulcer[5] has demonstrated an achlorhydria in over 88 per cent of the cases and probably because of this, recurrent gastric and gastrojejunal ulcers have not been observed. It is our belief that gastroenterostomy should never be done for *gastric* ulcer. If the lesion is so massive that resection appears impossible, then a preliminary jejunostomy for alimentation[6] seems a logical procedure. Following this, the stomach is put at partial physiologic rest and the ulcer should regress so in size that a partial gastrectomy may be performed several weeks later with comparative ease and safety.

The operative procedure may present technical difficulties, especially in penetrating ulcers. The method of resection differs somewhat from that described for duodenal ulcer,[7] for it is usually done in a retrograde fashion. The duodenum is transected first, so that the stomach may be gradually mobilized and reflected to the left, affording better exposure of the posterior surface of the stomach, an area frequently involved by ulceration. The technique which is followed at the present time will be described only briefly. The right gastric and right gastroepiploic arteries are ligated just distal to the pylorus, at which point the duodenum, which is usually mobile, is transected. The distal duodenum is closed with a chromic catgut suture of the Connell type and reinforced by a continuous linen Lembert suture. The duodenal stump is then buried against the head of the pancreas with a continuous plain catgut suture. There was usually very little difficulty in securing an adequate closure of the duodenum unless it was the seat of previous or active ulceration. However, if there was any doubt as to the competence of the suture line and a dehiscence was a possibility, the stump was drained with a rubber dam introduced through a right subcostal stab incision. This was done in nine instances. The gastrocolic omentum was then divided transversely toward the left between artery clamps applied below and parallel to the vascular epiploic arch, and the left gastroepiploic artery was ligated high on the greater curvature. The stomach was then carefully reflected to the left, exposing its posterior surface. Any adhesions which were present in the lesser omental sac were carefully divided, constant watch being made for any distortion of the middle colic artery. Occasionally

the stomach was firmly glued to the pancreas by a posterior penetrating ulcer, and separation could be accomplished only by sharp dissection.

In high lying ulcers, in order to mobilize the stomach more freely so that the lesion could be excised, it became necessary to ligate the left gastric artery close to its origin from the celiac axis. Originally, the part of stomach proximal to the ulcer was divided between rubber covered clamps unless the extent of the resection made their application impossible. During the past two years we have transected the stomach between a double line of clips laid down by the DePetz sewing machine and have found that this could be done even if the resection was made close to the esophagus. Following resection, gastrointestinal continuity was restored by an isoperistaltic terminolateral gastrojejunostomy of the Hofmeister type. In the first seventeen cases, a terminolateral anastomosis was made posterior to the colon. We have now discarded the posterior retrocolic type of gastrojejunostomy, having been impressed with the simplicity and the technical advantages of restoring gastrointestinal continuity *anterior* to the colon using a short proximal loop of jejunum about six inches long. Furthermore, we have noted no differences between this and the posterior anastomosis in either the immediate postoperative period or in the follow-up observation of patients. In the beginning of this series, the Murphy button was used in seven patients to restore gastrointestinal continuity in those instances in which, because of a high resection, a short proximal gastric segment remained. With added experience, the suture technique of anastomosis has been found feasible in all types of gastric resection and therefore the use of the Murphy button has been practically eliminated. Enteroenterostomy, which was thought to be necessary in high resections, has been discarded. It was performed only once in this series.

In nine cases in which either a very high gastric resection had been performed, or in which a marked preoperative dilatation of the stomach increased the possibility of postoperative gastric atony, a complementary jejunostomy for alimentation was done. This procedure and its advantages have been adequately described elsewhere.

Although subtotal gastrectomy with the removal of the ulcer is undoubtedly the procedure of choice, there were six cases in which the antrum and pylorus were removed, but the ulcer was left in situ. The lesion in four cases was a penetrating ulcer high on the lesser curvature, and in two cases the ulcers were juxta-esophageal in location. The general physical condition in four of the patients was so poor that an excessively high resection necessary to remove the ulcer would have been extremely hazardous. In the two patients with juxta-esophageal ulcers, a total gastrectomy would have been necessary if the ulcers were to be removed. For this type of case, Madlener[8] in 1923 first suggested pylorectomy without removal of the ulcer. Flörcken[9] subsequently removed the pylorus and as much of the antrum as possible, calling the procedure "palliative gastric resection." This procedure has not had wide application. It has one major disadvantage—the lesion which is not removed may possibly be carcinomatous. In adjudging the merits of this procedure, one must remember that removal of the antrum and pylorus *of patients suffering from gastric ulcer* almost always results in an anacidity, and that recurrent gastric or gastrojejunal ulcers under these conditions are almost unknown. In our limited experience, residual gastric ulcers apparently heal after palliative gastrectomy and recurrences have not been noted clinically, gastroscopically, or roentgenologically. Two of these cases have now been followed more than seven years. It therefore seems difficult to ascribe the disappearance of these lesions as an involutionary

stage in the life cycle of an ulcer. The subject of palliative gastrectomy for gastric ulcer will be discussed in detail in a subsequent communication.

The median epigastric incision was routinely closed with heavy silk sutures taken through all the layers of the abdominal wall. The advantages of this type of closure are that it is extremely rapid and that evisceration almost never occurs. It is unfortunately accompanied by an appreciable percentage of postoperative hernias. For this reason, interrupted steel wire sutures embracing the peritoneum, muscle, and fascia are now being used in addition to silk.

POSTOPERATIVE COURSE AND COMPLICATIONS

Postoperatively, a Levin tube was left indwelling, and an intravenous infusion of saline and glucose solution, which was given throughout the operation, was continued. If there had been moderate blood loss or any degree of shock, the patient was given blood, plasma, or both. Adequate sedation was administered. Oral fluids were allowed within twenty-four hours after operation. Sulfonamides were administered only when there was a specific indication as, for example, pneumonia.

The Levin tube was removed about the third day, and was passed again twelve hours later. If there was evidence of gastric retention, the tube was either left indwelling again for a two-day period, or was passed every twelve hours and the stomach completely emptied. The patients were encouraged to move about in bed. The sutures were removed in twelve days, at which time most patients were permitted out of bed.

Fourteen patients developed pulmonary lesions, most of which were atelectatic bronchopneumonias. This complication was rendered much less serious by the use of sulfonamides. If evidences of massive atelectasis or a marked accumulation of bronchial mucus was present, a bronchoscopy was rapidly done, and a mucous plug or the diffusely distributed mucus was removed. Recovery following this procedure, which was usually performed in the patient's bed, was prompt and very dramatic.

Two patients developed transient attacks of auricular fibrillation, and another sustained a coronary artery thrombosis with rapidly ensuing heart failure, pulmonary edema, and death.

There were two cases of gastric ileus, one of which was severe. The possibility of this had been anticipated and a complementary jejunostomy for alimentation had been done at the time of the original operation. In the other patient, the gastric atony was mild and subsided with conservative therapy.

A duodenal dehiscence occurred in three instances among the nine patients in whom drainage was carried out. One of these terminated fatally. While drainage does not always afford protection from the consequences of duodenal leak, it often prevents a fatal peritonitis or subphrenic abscess.

CAUSES OF DEATH

In this series of forty-two consecutive gastrectomies for gastric ulcer there were two deaths. One occurred following a subtotal gastrectomy, one following a palliative gastrectomy.

CASE 3 (No. 505682).—M. W., a 54-year-old woman, a known diabetic, entered the hospital, May 20, 1943, for the relief of abdominal pain of four years' duration. Ten years prior to admission she had had a cholecystectomy. She had been treated at various clinics for arthritis of the spine without relief. More recently she had noticed a few tarry stools, weight loss of eight pounds, occasional vomiting, and anorexia.

Physical examination disclosed an elderly appearing woman, exhibiting evidences of marked arteriosclerosis. There was tenderness in the midepigastrium and a well-healed right upper quadrant scar was noted. The liver was just palpable.

The hemoglobin was 63 per cent. Blood urea was 12 mg. per cent; blood sugar was 220 mg. per cent. The urine contained 1 per cent sugar. The stools contained occult blood on some occasions. The free gastric acidity was 60 millimoles, combined 76 millimoles. Gastrointestinal x-ray picture (made just before admission to the hospital) disclosed a penetrating lesion of the lesser curvature of the stomach. The electrocardiogram disclosed changes indicative of myocardial damage with previous coronary occlusion (posterior wall infarction).

The patient was treated medically for five weeks without improvement in her condition. The diabetes was controlled with diet and insulin. A preoperative diagnosis of carcinoma of the stomach was made. Exploration was performed through a median epigastric incision. There were many adhesions binding the duodenum and stomach to the undersurface of the liver. A huge ulcer was found on the lesser curvature of the stomach extending down from the re-entrant angle to the duodenum. The duodenum was stenotic and fibrotic and was the seat of an acute ulcer. The duodenal mobilization and closure were extremely difficult, and because the line of suture appeared insecure, the area was drained with a rubber dam made to emerge through a right subcostal stab incision. A subtotal gastrectomy with an antecolic terminolateral gastrojejunostomy and complementary jejunostomy for alimentation were performed.

The pathologic report of the specimen was chronic peptic ulcer of the stomach; duodenal ulcer; duodenum showing acute and chronic inflammation throughout the wall.

Postoperatively the patient did not do well. The temperature almost immediately rose to 105.6° F. and bile appeared along the rubber dam drain within a few hours. The abdomen became tender and rigid, the pulse rapid, and the blood pressure barely obtainable. Despite all forms of supportive therapy the patient died thirty-six hours after operation.

Post-mortem examination (No. 12543) disclosed a generalized peritonitis, due to a Welch bacillus, originating from a duodenal dehiscence.

CASE 4 (No. 416478).—J. G., a 58-year-old man, was re-admitted to the hospital, Nov. 10, 1937, complaining of abdominal pain of one year's duration. He had been treated five months previously for a known gastric ulcer. He improved with medical therapy and was discharged. However, he continued to lose weight and strength, the pain recurred and became progressively more severe, and vomiting began to occur with increasing frequency.

Examination disclosed a chronically ill man, showing evidences of recent weight loss and severe arteriosclerosis. There was slight tenderness in the epigastrium.

The hemoglobin was 83 per cent; urine was negative. The Rehfuss test meal showed a free acid of 70 millimoles and a total acid of 84 millimoles. Gastrointestinal x-ray showed a penetrating gastric ulcer about one inch in diameter on the posterior wall near the lesser curvature in the lower part of the fundus. Gastroscopy disclosed a punched-out ulcer high on the lesser curvature. The electrocardiogram disclosed occasional extrasystoles.

The patient was treated medically but his pain continued and it was finally felt that surgical intervention was imperative.

At operation an ulcer about two inches in diameter was found on the lesser curvature just below the esophagus. It was penetrating into the pancreas. There was evidence of a healed duodenal ulcer. It was felt that removal of the gastric ulcer would entail a total gastrectomy which was not indicated. Accordingly, a palliative partial gastrectomy was performed, leaving the ulcer in situ. The resected specimen after excision measured 9 cm. along the lesser curvature and 14 cm. along the greater curvature. Gastrointestinal continuity was restored by a retrocolic isoperistaltic gastrojejunostomy of the Hofmeister type.

The first postoperative morning the temperature was 100° F., pulse 100, tongue moist, abdomen soft. Later that day, however, the patient suddenly developed acute pulmonary edema, together with marked shock. The pulse rose to 190 and the blood pressure fell to 64/40. The patient exhibited no evidences of bleeding. He was placed in an oxygen tent, a phlebotomy performed, 50 per cent glucose administered intravenously, and morphine and atropine were given by hypodermic injection. Despite energetic therapy, the patient died two hours after the onset of the attack. The medical consultant who saw the patient felt that the incident represented an acute coronary artery thrombosis with left ventricular failure.

A post-mortem examination could not be obtained.

SUMMARY

A series of forty-two consecutive ward patients suffering with chronic gastric ulcer, treated surgically, is presented.

The chronicity of the history is stressed and the indications for surgical intervention are discussed.

The difficulties in the interpretation of the acid figures, the roentgenologic and gastroscopic findings as aids in the differential diagnosis between benign ulcers and ulcerating carcinomas are emphasized.

A plan of preoperative preparation is detailed.

The technique of subtotal gastrectomy which was used in thirty-six cases and palliative gastric resection which was employed in six patients is briefly outlined.

Postoperative care and management of the complications are described.

The two fatalities in these forty-two cases are outlined.

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THE HYPOCHLOREMIC STATE IN SURGICAL PATIENTS

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COLLER and his associates[1] have made a very important contribution to the postoperative care of surgical patients by revising their "clinical rule"[2] for the administration of salt solution. They felt that because of the relatively high incidence of "salt intolerance" following general anesthesia, salt solution should not be given the day of operation or on the first two postoperative days. The fluid requirements should be met with glucose in distilled water. They stated that the experience of years regarding the toxicity of isotonic sodium chloride has been forgotten. Trout[3] over thirty years ago was quoted, "Even we surgeons know of the wonderful improvement in some patients with nephritis when placed on a salt-free diet, and all of us realize there is a transient renal irritation or possibly nephritis following the majority of anesthetics and infections." Coller and his associates also believed that great care must be used in administer-

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ing isotonic salt and Ringer's solution to patients who are hypoproteinemic, anemic, acidotic, or oliguric. Patients who tolerate salt poorly after operation are classified into three groups of predominant and fairly distinctive symptom and sign complexes. They recommended that the correction of uncompensated extracellular fluid deficiency states be made upon the basis of physiologic response to test doses of salt, rather than on the basis of the plasma chloride, the CO_2 combining power, the nonprotein nitrogen, plasma protein, or the hemoglobin levels.

I am in complete agreement with the need for extreme caution in the administration of salt as just discussed, but I wish to issue the emphatic warning that severe hypochloremic states may occur when patients are on a restricted salt intake. If active therapy (with saline solution) is not instituted in these cases, serious results may ensue. I wish to review briefly the manifestations of hypochloremia and attempt to establish criteria for the administration of salt in these patients who so frequently have a complicating abnormal but varying loss of salt (for example, from bile fistula).

Clinical Manifestations.—The onset of clinical hypochloremia is very insidious; the manifestations are similar to those of salt edema. Unless attention is paid to the extremely low blood chloride reading, and the possibility of the hypochloremic state is appreciated by studies of the clinical picture, salt may be withheld entirely instead of being given in large quantities. The most important diagnostic lead is obtained by realizing that a clinical state has been present when large amounts of electrolytes and chlorides have been lost without being compensated (for example, bile fistula, vomiting, high intestinal fistula, etc.). The clinical picture presents itself rather abruptly in the acute cases, as one of shock (blood chlorides below 300 mg. per cent). The skin is cold and clammy and the patient complains of extreme weakness. The pulse and blood pressure are usually unobtainable. Within forty-eight hours the urinary output has acutely decreased to 100 c.c. or less for twenty-four hours, with a corresponding rise in the nonprotein nitrogen. The body temperature is characteristically subnormal and in the neighborhood of 97° F. The blood chlorides are extremely low. A wrong diagnosis may lead to an early fatality due to the use of temporizing procedures or that utilized in the general therapy of shock. Hypochloremia which has progressed to the point of producing symptoms is an acute emergency and unless several thousand cubic centimeters of physiologic saline solution (containing 54 to 72 Gm. of salt) are given parenterally within twenty-four hours, it is unlikely that the patient will recover. It is obviously a fatal mistake to confuse such a case with one of salt edema which is easily done except for the presence of *edema* in the latter instance; in salt intoxication, a diffuse and pronounced dependent edema is rarely absent. An additional differential point is that, as a general rule, in hypochloremia the urine does not reveal casts, albumin, red cells, etc.

The clinical cases to be presented differ as to the mechanism of the chloride loss. The first case, as presented in detail in the Case Reports, concerned a 23-year-old girl with extensive granulating areas following a burn which involved 35 per cent of the body surface. Her anemic and hypoproteinemic state was adequately corrected with whole blood and plasma. However, we failed to appreciate the fact that huge quantities of chlorides and other electrolytes could be lost through the extensive granulating areas, that is until a picture of acute prostration and impending shock presented itself with a blood chloride reading of 327 mg. per cent. Ten thousand cubic centimeters of parenteral fluids containing 81 Gm. of salt were needed to elevate the blood chloride reading to

445 mg. per cent on the following day (normal 450 to 500 mg. per cent). The amount of salt given here is considerably more than that which would be given by the Coller "clinical rule," and perhaps was more than was actually needed; nevertheless, the clinical response was immediate and ideal. Hypochloremia in the second case was produced by excessive loss of chlorides through vomiting. The high intestinal obstruction was caused by a carcinoma of the distal end of the stomach. In the third and most interesting case the patient developed hypochloremia because of cholorrhea through a persistent external biliary fistula created when the common bile duct was opened to drain a suppurative cholangitis; a carcinoma of the ampulla of Vater produced the biliary obstruction. This patient presented the most acute picture of the hypochloremic state and was found early one morning in a state of extreme prostration and severe surgical shock. The patient's blood chloride reading at this time was 270 mg. per cent. Approximately 6,000 c.c. of fluids containing 54 Gm. of salt were needed to restore the blood chloride reading to normal. A daily maintenance dose of 40 to 50 Gm. of salt were required to keep the patient from relapsing

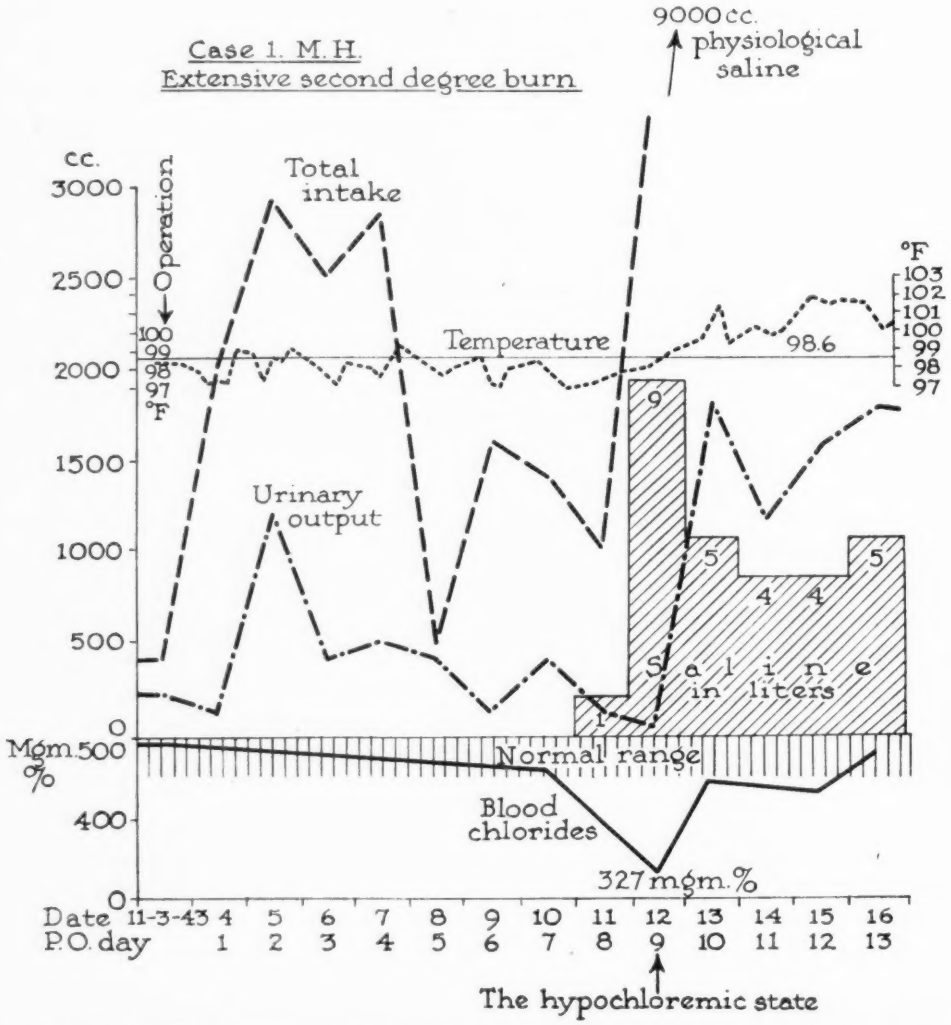

Fig. 1.—Postoperative course of extensive degree burn showing the subnormal temperature and decreased urinary out-put as acute hypochloremic state was approached on ninth postoperative day. The blood chloride at this point was 327 mg. per cent. The miraculous response after intensive salt therapy on the ninth postoperative day is shown by the increased urinary out-put from 50 to 1,850 c.c. during the next twenty-four hours, and a rise of the subnormal temperature to above normal. The blood chloride level required four to five days before it returned to normal limits in spite of the large amount of salt given to the patient.

into the hypochloremic state because of the excessive amount lost through the external biliary fistula. The output of bile approximated 3,000 c.c. daily. The chloride content of the liver bile averaged 740 mg. per cent (normal reading for liver bile 580 to 650 mg. per cent). The chloride content of this patient's bile was slightly above the normal average. The large amount of bile lost daily with its high percentage of sodium chloride obviously contributed greatly to the several recurrences of the hypochloremic state in this patient. A fourth case of painless progressive icterus due to a carcinoma of the common hepatic bile duct is very similar to the third case except for the absence of a complicating suppurative cholangitis. This patient also needed a very high daily maintenance dose of salt to compensate for that lost by the bile fistula.

CASE REPORTS

CASE 1 (No. 91038).—M. H., a 23-year-old white woman, entered the Research and Educational Hospital, Sept. 24, 1943, with extensive second and third degree burns involving both arms, chest, and neck. The granulating infected areas involved 30 to 35 per cent of the body surface. Early contractural scar deformities were present in the neck and over the shoulder and elbow joints. The burn followed the explosion of a kerosene stove nine weeks previously. After the patient's blood chemistry and hematologic determinations had been corrected, the granulating areas were grafted at ten-day intervals. On the eighth postoperative day following the fifth skin-grafting operation, the patient developed an acute hypochloremic state with a blood chloride reading of 327 mg. per cent. Her essential complaint in the first eight postoperative days had been mild crampy abdominal pain, apathy, anorexia, excessive thirst, extreme weakness, and vomiting of small amounts of bile-stained fluid with moderate abdominal distention. At first it was thought that the patient had an acute mechanical intestinal obstruction or possibly a salt intoxication. However, a flat x-ray film of the abdomen was characteristic of a paralytic ileus as dilated loops were noted throughout both the large and small bowel and a very rapid response was obtained with intensive salt therapy. Previously the usual conservative treatment of abdominal distention had been of no avail and the dramatic therapeutic response was not obtained until massive salt treatment was instituted parenterally. The very low blood chloride reading of 327 mg. per cent indicated the necessity of intensive salt therapy. The onset of the acute hypochloremic state on the eighth postoperative day presented itself as a picture of shock and prostration and was accompanied by a subnormal temperature of 97° F., a cold clammy skin, drowsiness and oliguria of 50 c.c. during the past twenty-four hours. The patient's blood chlorides were elevated to 446 mg. per cent within twenty-four hours by the administration of 9,000 c.c. of physiologic saline solution subcutaneously. The urinary output which amounted to 50 c.c. during the previous twenty-four hour period responded very readily to this therapy. The next twenty-four hour urinary output was 1,820 c.c. The nonprotein nitrogen dropped from 55.7 to 34 during the same period. The patient made an uneventful recovery thereafter, being given a maintenance dose of 36 Gm. of salt daily for several days to prevent any relapse.

CASE 2 (No. 95666).—L. C., a 65-year-old Negro man, entered the Research and Educational Hospital Aug. 18, 1944, complaining of vomiting small amounts of sour fluid after every meal for the past nine weeks. In addition, nausea, anorexia, and heartburn were prominent symptoms. He had lost nine pounds of weight during the ten days prior to entrance and was extremely weak when admitted to the surgical ward. At this time the abdomen was moderately distended and he complained of intractable crampy abdominal pain. Gastric aspiration yielded 1,200 c.c. of greenish-brown fluid on the day of entrance, but with no relief of the crampy abdominal pain. Laboratory examination revealed no free hydrochloric acid and 40 degrees of total acid. On the second hospital day the patient complained of extreme weakness. While waiting on a stretcher in the x-ray department for an x-ray picture to be made, he complained of symptoms of collapse. He was returned to bed immediately; upon examination he was very cyanotic, cold, clammy, and obviously in shock. The usual treatment of shock failed; the patient died within three hours. The blood chloride reading on the day of death was 272 mg. per cent. A clinical diagnosis of hypochloremia was not made and the blood chemistry determinations were not available until after death. Urinalysis revealed only a trace of albumin and the nonprotein nitrogen reading was 112 mg. per cent. The subnormal temperature of 98° F. obtained on admission dropped to 97° F. the following morning where it remained until death occurred thirty-six hours later. Post-mortem examina-

tion disclosed a carcinoma of the pylorus with chronic high intestinal obstruction complicated by an aspiration bronchopneumonia. The patient died less than forty-eight hours after entrance. No doubt the bronchopneumonia was an important contributing factor in this patient's death, but we are willing to admit that prompt recognition and treatment of his hypochloremia might have saved him.

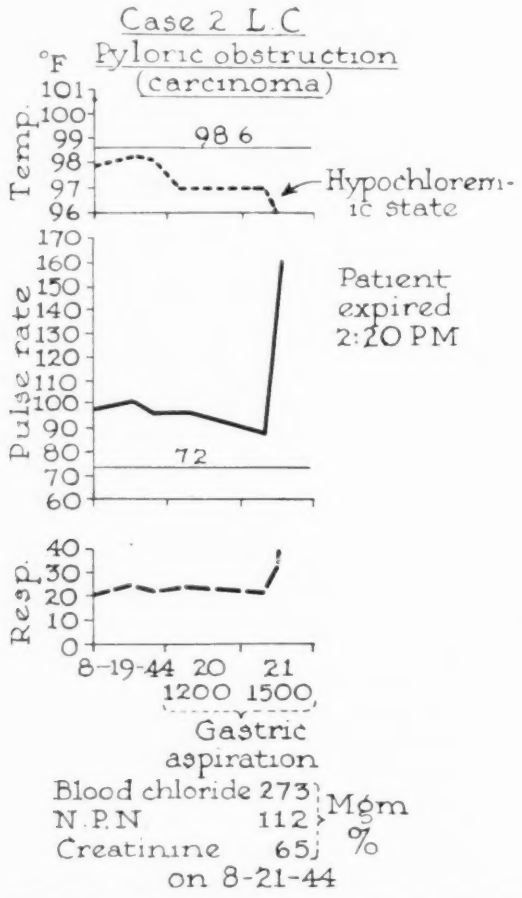

Fig. 2.—Patient sustained a tremendous loss of blood chlorides by vomiting small amounts over long period of time. He entered the hospital in hypochloremic state which was not recognized clinically. Due to his extreme weakness which was characteristic of the acute hypochloremic state, he developed aspiration bronchopneumonia and died within several hours. Blood chlorides at this time were 273 mg. per cent, with an extrarenal azotemia and a nonprotein nitrogen level of 112 mg. per cent.

CASE 3 (No. 82396).—F. S., a 56-year-old white man, entered the Research and Educational Hospital April 14, 1942, complaining of intermittent chills and fever for the past two or three years. These attacks had become worse during the past six weeks and had been accompanied by extreme weakness and fatigue, pain in the right loin, and migrating body pains. Physical findings were essentially negative except for questionable icterus and a large liver. He developed chills and a septic type of fever with increase of the icterus and a white blood count of 17,000. Exploratory laparotomy was performed April 22, 1942. The gall bladder was distended but not thickened. Aspiration of a common bile duct of normal size disclosed thin bile but no pus. However, numerous gram-positive cocci and gram-negative rods were found on stained smear. The head of the pancreas felt thickened but a positive diagnosis of carcinoma could not be made. The common bile duct was opened for drainage because of the numerous bacteria present. No stones were found. T-tube drainage was used with remarkable curative effect on the septic course. The patient's postoperative course was uneventful except for mild crampy abdominal pain, moderate distention, and a profusely draining external biliary fistula. On the sixth postoperative day, at morning rounds, the patient was found in obvious shock. His skin was cold and clammy and he complained of extreme weakness and apathy. The patient's pulse and blood pressure were unobtainable and rectal temperature reading was 97° F., at which level it remained for several days thereafter. Blood chloride determination obtained at this time was 270 mg. per cent. The chloride content

of the bile drainage was 740 mg. per cent. The total amount of bile drainage from the T tube the day before the acute hypochloremic state developed was 3,700 c.c. with a total of 12,200 c.c. during the previous five days. The daily urinary output dropped from 3,000 c.c. to 600 during the previous forty-eight hours. Six thousand cubic centimeters of physiologic saline solution containing 54 Gm. of salt were given parenterally in the first twenty-four hours. The following five days 36 Gm. of salt were given daily in conjunction with intravenous fluids, glucose, and adrenal cortical extract. The patient responded very well after the intensive salt therapy of the first twenty-four hours. The first blood chloride reading taken five days after the onset of the hypochloremic state was 447 mg. per cent (normal 450 to 500 mg. per cent). The patient had received approximately 200 Gm. of salt since the onset of the acute collapse five days before. On June 18, 1942, the patient again relapsed into a hypochloremic state with a blood chloride reading of 330 mg. per cent and complained of extreme weakness and apathy. This relapse was much less severe than the first attack three weeks previous. Oral salt in the amount of 5 Gm. daily supplemented by 18 Gm. intravenously maintained his blood chlorides within normal limits thereafter. He was discharged on June 27, 1942, with a diagnosis of chronic pancreatitis of the stenosing type.

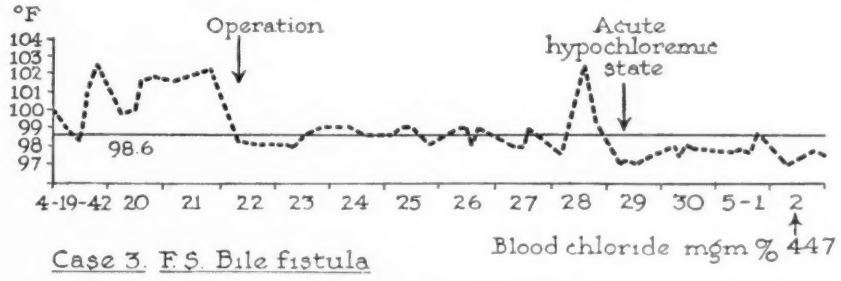

Fig. 3.—Postoperative temperature chart of patient with a carcinoma of the ampulla of Vater. Loss of chlorides was extreme through the external biliary fistula produced at operation. The acute hypochloremic state developed gradually and is characterized by the gradual development of a subnormal temperature which reached 97° F. during the acute hypochloremic state on April 29, 1942. The blood chlorides three days later were 447 mg. per cent: on the morning of the acute hypochloremic state the blood chlorides were 272 mg. per cent.

Approximately one month later, on July 16, 1942, the patient re-entered the hospital with another relapse into the hypochloremic state. The blood chloride reading at this time was 383 mg. per cent. The previous week had been very sultry with the temperature in the nineties. The patient's external biliary fistula was still draining profusely. After the blood chlorides had been balanced, exploratory laparotomy revealed a large tumor mass involving the porta hepatis with metastatic nodules in the liver. Biopsy disclosed a metastatic duct carcinoma of the pancreas or bile ducts, Grade III. The patient died Oct. 5, 1942, approximately five weeks after the last operation.

CASE 4.—W. D., a 57-year-old, very poorly nourished white man, entered the Research and Educational Hospital Jan. 19, 1942, complaining of a painless, progressive jaundice of

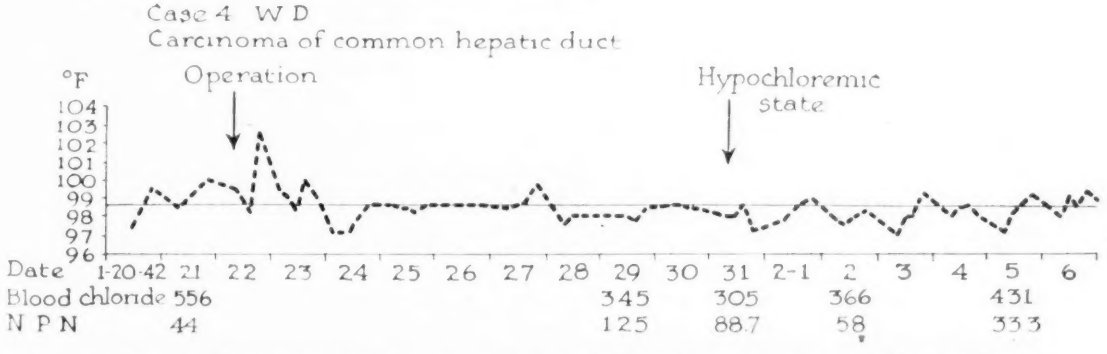

Fig. 4.—This patient had an external biliary fistula with extreme loss of chlorides due to the extensive loss of bile through the fistula. The postoperative course shows the gradual lowering of the temperature and also the gradual lowering of the blood chlorides which reached 305 mg. per cent (blood chlorides) during the hypochloremic state. The body temperature was subnormal at this point and gradually rose to approach normal after the blood chlorides were elevated. It is also noted that the nonprotein nitrogen returned to normal after the blood chlorides returned to normal.

five months' duration. Exploratory laparotomy revealed a carcinoma of the common bile duct. This was resected and an external biliary fistula established; no attempt was made to establish an internal biliary fistula at this time because of the patient's precarious condition. Due to the loss of at least 2,000 c.c. of bile daily, the patient relapsed into the hypochloremic state several times in spite of a relatively large intake of salt. The symptoms of crampy abdominal pain, subnormal temperature, cold clammy skin, nausea, and vomiting accompanied by hiccoughs were similar to the other cases reported. A jejunostomy was performed March 11, 1942, to facilitate the return of bile to the gastrointestinal tract. The patient expired on March 14, 1942. The autopsy findings disclosed a bronchopneumonia of the left lower lobe and multiple liver abscesses as the immediate cause of death.

COMMENT

I am in accord with Coller and his associates relative to the caution which should be used in the administration of salt in the surgical patient. This is especially important in the older age group of patients postoperatively, because any additional load, no matter how slight, may be too much for the presenile kidney. However, there are exceptions (particularly when there is abnormal loss) as Coller and his co-workers have stated, where salt therapy is allowed and needed postoperatively. The four clinical cases presented are dramatic exceptions to the "no salt rule postoperatively." In fact, it is extremely important that the hypochloremic state be recognized immediately for not only is salt indicated, but in large amounts and rapidly. This need for salt may total as much as 80 to 100 Gm. of sodium chloride in twenty-four hours for a patient whose blood chloride reading is less than 300 mg. per cent, particularly when the source of the chloride loss persists. Whether the electrolytes are to be given in physiologic saline, Ringer's, or Hartmann's solution will depend upon whether there is a compensatory alkalosis or a complicating uremic acidosis to be treated. It might appear that salt given in the amount discussed, to an older patient with impaired kidney function, postoperatively, would necessarily throw him into a fatal uremia and anuria. Such would, of course, be true if a severe hypochloremia was not present and the source of the loss persistent.

Although a relatively rare clinical entity, the hypochloremic state deserves enough publicity so that it will be readily and easily recognizable. It is equivalent to "heat exhaustion" passing into the subacute or chronic phase due to the persistence of the chloride loss. Spontaneous recognition is difficult due to its rarity and the bizarre clinical picture pesented. The physician must be aware of the clinical entities which may allow the loss of sufficient chlorides to produce the hypochloremic state. The conditions most commonly allowing the loss of large quantities of electrolytes are gastroduodenal drainage, pyloric obstruction with vomiting, persistent external biliary fistulas, high intestinal fistulas, electrolytic loss from large granulating areas, persistent fever and excessive sweating from a long operation during the sultry weather or both. Emergency facilities for determining blood chloride levels at night or over week ends should be made available. One patient (Case 2) entered the hospital Saturday afternoon and died the following Monday afternoon shortly after a blood chloride reading of 273 mg. per cent was returned, but obviously too late to aid in treatment. The diagnosis of hypochloremia was not made clinically; we consider this error a serious and preventable one because of the severity of the symptoms.

The *clinical manifestations* of the hypochloremic state may be classified as either prodromal or advanced. The advanced symptoms of the hypochloremic state are acute and very similar to those of surgical shock and extreme prostration. They are usually characterized by a subnormal temperature of 97 to 98°

F., a systolic blood pressure of 80 or below, and a very soft easily compressible pulse which is almost unobtainable. The skin is cold and clammy, and excessive thirst accompanied by extreme weakness and prostration are likewise common. These acute advanced symptoms may be preceded for several days by the prodromal symptoms which consist of mild cramplike persistent abdominal pain, nausea, moderate abdominal distention, and the vomiting of small amounts of bile-stained fluid repeatedly. In addition the patient may appear languid, drowsy, and apathetic and not infrequently may develop an intractable hiccough. Anorexia is almost always present and bowel movements or flatus is singularly absent. Other fairly constant findings are an oliguria of 100 c.c. or less with the symptom complex of uremia. The oliguria and uremia are apparently on an extrarenal basis as they both rapidly return to normal when the blood chlorides are elevated. The similarity of the symptom complex of the hypochloremic state to the clinical picture presented by salt intoxication, the "acute abdomen," postoperative ileus, and intestinal obstruction due to nutritional edema make them extremely difficult to differentiate, except for the low blood chloride reading and the clinical states mentioned, which allow an uncompensated loss of chlorides.

The importance of early diagnosis of the hypochloremic state cannot be minimized. The low chloride level of the body fluids and tissues is rapidly fatal because of the uncompensated alkalosis and extrarenal azotemia produced with its accompanying state of severe shock. The extreme weakness, lowered metabolic rate, and shock lead inevitably to other complications such as intestinal ileus, aspiration and hypostatic pneumonia, and the onset of a vicious cycle. Therefore, prophylaxis by recognizing the possibility of its occurrence through chloride determinations in the suspected case is very essential. Active therapy should revolve around massive fluid and salt therapy, preferably intravenously. Experimentally, Soffer and associates[4] have shown that the intravenous injection of salt is retained in the tissues much more readily when supplemented by cortical adrenal extract parenterally.

Shock due to the acute hypochloremic state will not respond to the usual therapy of blood, plasma, and nonspecific intravenous fluids. Immediate and specific active therapy consisting of massive doses of salt and fluids is indicated parenterally. This should be supplemented by adrenal cortical extract which materially aids the body tissues in retaining the sodium and chloride ion. From 6,000 to 10,000 c.c. of physiologic saline solution parenterally may be necessary within the next twenty-four hour period to prevent a fatality. The Coller "clinical rule" as mentioned previously in the text is an extremely accurate guide in salt replacement therapy. This allows the patient .5 Gm. of sodium chloride per kilogram of body weight for every 100 mg. per cent below 560 which is the lower limits of normal for the plasma chloride reading. Once the hypochloremic state has been corrected, a daily maintenance dose should be established by the "volume-for-volume" method as suggested by Coller, which is based on the amount of electrolyte still being lost. This can be supplemented by daily blood chloride determinations. The patient's clinical state and his physiologic response to appropriate test doses of salt are other valuable guides as mentioned previously. Obviously too much salt should not be given because salt intoxication and edema are almost as likely to lead to a fatality as hypochloremia. The miraculous clinical cures obtained by massive salt therapy are illustrated by Cases 1 and 3. The possibility of a rapidly fatal clinical course is illustrated by Case 2, in which the patient had a carcinoma of the pylorus with

remarkably little vomiting but a blood chloride reading of 273 mg. per cent. He died less than forty-eight hours after admission. The severity of his hypochloremia was not appreciated until just before death.

The interpretation of blood chloride readings is important as the normal values vary, depending on whether the whole blood or the plasma chloride reading is being used. The normal whole blood chloride values are 450 to 500 mg. per cent. The plasma chloride values are 580 to 650 mg. per cent. The lower value of the whole blood is due to the sodium chloride content of the red blood cells being much below that of plasma and serum. Therefore, knowledge of what type of chloride estimation is being performed and what the normal limits are for that particular estimation is essential. The salt content of bile is approximately the same as that of plasma or serum. However, it may be slightly higher as the liver has some power of concentration even after cholecystectomy. The chloride estimations used in this paper are for whole blood (normal 450 to 500 mg. per cent).

Obviously, one must be careful not to overload these patients with too much salt once they have been rescued from the acute lack of sodium chloride. Therefore, daily blood chloride determinations should be routine follow-up control as well as the physiologic response of the patient to test doses of appropriate salt solution. As is well known, salt edema alone or in combination with nutritional edema can produce complete intestinal obstruction at the anastomotic site postoperatively. The happy medium may be extremely difficult to obtain in patients unable to take anything orally, especially when losing electrolytes by the methods just mentioned.

SUMMARY

Four clinical cases of the *hypochloremic state* occurring in surgical patients are presented. The necessity for immediate recognition and differentiation from acute surgical conditions demanding operative intervention such as the "acute abdomen" or from salt intoxication and postoperative ileus which demand radically different nonoperative therapy is emphasized. In the hypochloremic state an abnormal loss of electrolytic fluid by gastroduodenal suction, pyloric obstruction, external or high intestinal fistulas, extensive granulating areas, and excessive loss of perspiration or allied causes is always demonstrable. The immediate postoperative period or warm sultry weather is the time period when this state is most likely to occur, especially when the abnormal loss of salt is prolonged. The loss of sodium chloride may become pernicious if not corrected, due to the accompanying dehydration, compensatory alkalosis, and further loss of chlorides by vomiting which is almost always present secondarily in the hypochloremic state. Immediate diagnosis is of vital importance because patients in the acute hypochloremic state are as ill as those with acute intestinal obstruction, and may die within a relatively short period of time unless massive salt therapy is instituted.

The various clinical features may be summed up as follows. The possibility of the hypochloremic state should always be kept in mind when considering surgical complications, especially postoperatively. It should be noted whether any abnormal loss of electrolytes has occurred and particularly whether or not such loss has been present for several days without being compensated for. If in doubt, an emergency blood chloride determination should be obtained. Any reading in the neighborhood of 300 mg. per cent or lower demands immediate consideration in therapy. The value of an emergency blood chloride determination is tragically demonstrated in the patient (Case 2) whose blood chloride read-

ing returned Monday noon with a value of 273 mg. per cent shortly after his death. He had entered the hospital Saturday afternoon, thirty-six hours previously, and had had an incorrect clinical diagnosis.

The clinical manifestations in the acute hypochloremic state may be exemplified in a patient suddenly found in shock with a cold clammy skin, subnormal body temperature, unobtainable or weak pulse, systolic blood pressure of 80 or below, with complete prostration and at least partial mental confusion. This acute shocklike state is found when the blood or plasma chloride reading drops to approximately 150 mg. per cent below the lower limits of normal. For several days previously this acute hypochloremia may have been preceded by nonspecific prodromal symptoms such as the vomiting of small amounts of bile, abdominal distention, mild crampy abdominal pain, hiccoughs, inability to pass gas, and extreme weakness. The latter clinical symptoms are usually noted when the blood or the plasma chloride readings are between 50 to 150 mg. per cent below the lower limits of normal. The output of urine, bile, gastroduodenal suction, or vomitus during this prodromal period has usually been tremendous and is always more than the fluid and electrolytic intake. This leads to acute dehydration, oliguria, compensatory alkalosis, and extrarenal azotemia with the onset of the acute hypochloremic state and its accompanying shock. The alkalosis or acidosis is disregarded as this disturbance of the acid-base balance, along with the elevated nonprotein nitrogen, automatically returns to normal with the correction of the hypochloremic state. Gamble[5] has emphasized that sodium chloride given with an abundance of water will correct either alkalosis or inorganic acidosis, the kidneys excreting the unnecessary ion.

The specific therapy of acute hypochloremic prostration is massive salt and fluid replacement parenterally. Sodium chloride in amounts of 80 to 100 Gm. during the first twenty-four hours is occasionally necessary to bring the depleted patient out of the critical condition into which he has suddenly lapsed. A daily maintenance dose of 30 to 40 Gm. of salt may be necessary when the abnormal chloride loss is excessive and very difficult to control, as in Case 3. The Coller "clinical rule" for the replacement of sodium chloride is a valuable guide in the treatment of the acute hypochloremic state. As a general rule, no salt should be given to surgical patients during the first few postoperative days; however, occasional cases may arise where intensive salt therapy is definitely indicated.

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NEW TECHNIQUES FOR PARENTERAL FLUID AND DRUG ADMINISTRATION

I. Muscular Intubation

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DEVELOPMENT of modern plastics and discovery that they are well tolerated by the tissues have opened important fields beside their installation as prostheties. Investigators in the pharmacotherapy unit at Harvard (Drs. E. B. Astwood, J. F. Marchand, and B. Zimmerman) found that small tubes of vinyl chloride polymer were well tolerated in veins in the dog for many days of continuous infusion, and were less readily dislodged than cannulae. This suggested to them clinical application where cannulae, Lindemann needles, or even repeated venipunctures for infusions would ordinarily be used. I was invited to assist in development of the intravenous technique and its clinical testing. The highly gratifying results obtained and the methods developed will be described in subsequent publications. It is, of course, understood that venous intubation is in itself not new, but it is felt that use of the very fine and pliable but tough plastic tubes instead of the bulky, costly clot-promoting ureteral catheters or rubber tubes formerly used, is an important advance, particularly in eliminating the need for cutting down upon relatively small veins.

This communication is to call attention to a further development apparently not heretofore described—muscular intubation with plastic tubes, specially created for these purposes and flexible as ordinary twine.* It will be recalled that penicillin must be given parenterally (at least until proposed oral forms become applicable), and that because of its rapid destruction and excretion, intramuscular injection every three hours is standard practice. Use of an oily or poorly soluble menstruum has been proposed to reduce injection frequency, but raises further obvious questions as to variation in the effective concentration of drug and of untoward reaction from accumulated menstruum. In any case, the maddening repetition of the usual injections becomes a serious matter to the sick, weary, and nervous patient, interfering with sleep and sometimes growing to an obsession about needles.

Encouraged by success with venous intubation suggested by the Harvard group, it occurred to me that by inserting plastic tubes deeply into the muscle, injections could be given without disturbing the patient. It has been found clinically that one-half million units of penicillin may be given daily at the same site for one week with negligible reaction.

To facilitate injections an "ampule adaptor" was devised, to mount an ordinary small ampule cap on the external end of the tube. The nurse then merely tips up the cap, sterilizes it with iodine, and slowly injects into it the individual dose of penicillin. This may often be done without waking the patient. We have used sodium penicillin, made up in solution with physiologic saline so that the desired dose is contained in exactly 1 c.c. (or 1.2 c.c. in the case

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of a patient receiving 60,000 units in each dose). Patients to receive doses beyond this range of magnitude have been given a continuous elysis through the tube into the muscle, with for example 500,000 units dissolved in 240 c.c. of saline solution daily. This gives a high and constant titer in the body fluids with a surprising degree of freedom from local reaction. Patients who have received penicillin via plastic tubes, after experience with the usual method, are unanimous in keen appreciation of them. Instructions are given to move the involved muscles naturally, and if any local "full" feeling is noted after an injection, to rub the area gently to promote dispersal.

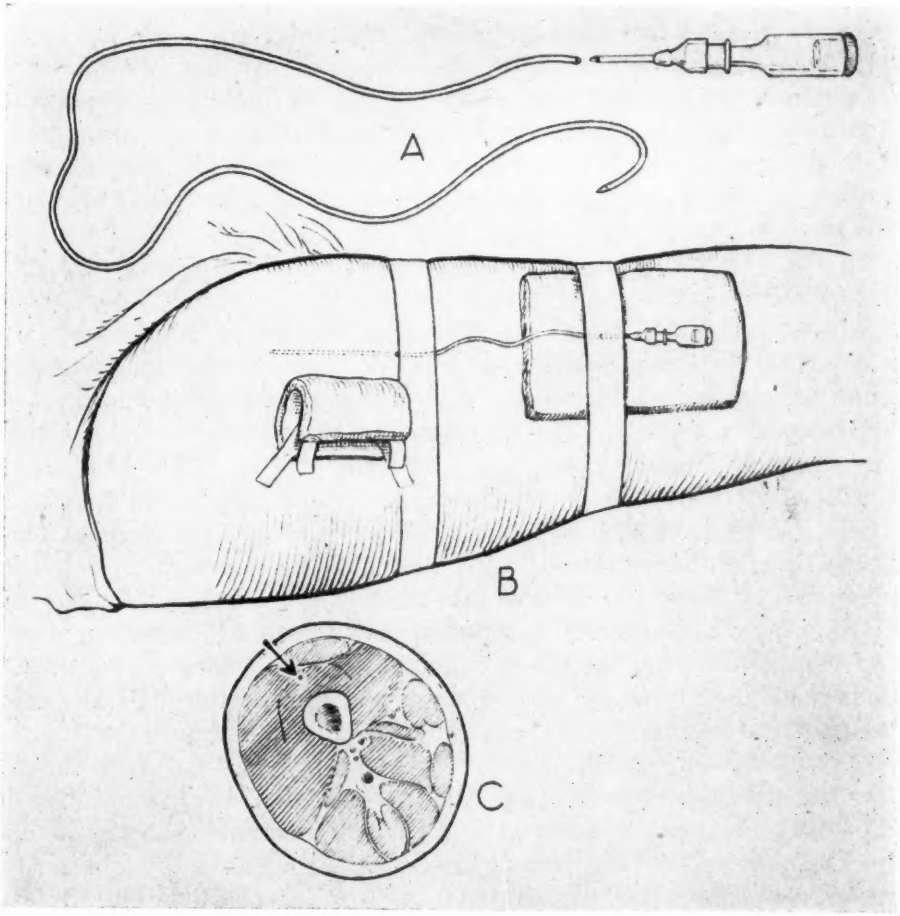

Fig. 1.—*A*, Enlarged view of tube and ampule adaptor. *B*, Side view of thigh, with covering compress removed and puncture dressing laid back, showing tubing as installed in outer side of right thigh. *C*, Cross section of thigh with tube lying deep in lateral musculature.

Nurses must be cautioned not to use this convenient little adaptor for injection of such substances as liver extract; the nonirritating nature of the tube naturally cannot alter the inadvisability of injecting certain medications repeatedly in one spot. Careful clinicians should find on further investigation that a number of medications ordinarily given by multiple injections are well tolerated when thus placed deeply into the muscle. Meanwhile this note is published in the hope of alleviating the real discomfort of the thousands receiving penicillin injections daily, some of whom refuse to continue medication of which they are in serious need. An application suggested by the originators of the plastic intubation, and by many who have seen it since, is in continuous spinal anesthesia. It offers obvious advantages, as it may be obtained finer

than the lead in a mechanical pencil, and despite its strength may be stretched over twice its length without breaking. Low cost permits discard after a single use. Spinal use will be discussed after suitable spinal techniques have been further studied. The tubing has also been placed through a tympanic perforation occurring in otitis media, for local penicillin therapy in the middle ear. Antral irrigation every three hours by indwelling plastic tubes has been similarly suggested. Details of the technique for muscular intubation follow.

The selected tubing passes readily through a 17 gauge needle. It is cut into twelve-inch lengths and sterilized by boiling for thirty minutes. The ampule adaptor consists of a Luer-tipped glass tube bearing a rubber ampule cap, and a dulled, short bevel, 22 gauge needle of one-half inch length. The glass tube can be made from the Luer tip supplied with most intravenous sets, cut and fire-glazed to give snug fit with a rubber cap. The entire adaptor is sterilized with an obturated 17 gauge spinal needle five and one-half inches long, which is used for introducing the tube into the muscle.* The stylet of the spinal needle prevents plugging of the needle mouth by fat particles during the insertion, so that the rather limp tubing may be readily pushed into the tissues as the needle is withdrawn.

The site is shaved if hairy, widely prepared with iodine and alcohol, and draped with three sterile towels. Sterile gloves should be worn. A dermal wheal of 1 per cent novocain is raised in midthigh at juncture of anterior and lateral aspects. The spinal needle is thrust smartly cephalad and slightly medially, deep into the vastus medialis muscle. It may be pushed up with the skin to gain as much depth as possible. The obturator is then withdrawn and the tubing (with end cut off squarely) is threaded into the needle. While the tubing is being pushed on, the needle is withdrawn; the tubing may be fed directly into the needle hub with thumb forceps to minimize tendency to buckling. After the needle has been withdrawn one-third of its length, the tubing may be released and observed. It should be dragged into the hub as the needle is further withdrawn, showing that the tissues have seized the tube tip. Pressure may then be applied on the overlying skin to aid in retaining the tubing as the needle is cautiously stripped back out of the thigh and off the tube. If the tubing should for any reason fail to lodge at full depth in the muscle (an India ink marker placed five inches from the tip before sterilizing is helpful), it should be entirely withdrawn and re-inserted—subcutaneous deposition of solution is a cause of discomfort, poor absorption, and pocket formation. The plastic tubing is taped directly to the skin by a piece of one-inch adhesive eight inches long, just below the point of emergence of the tube. It is desirable to be able to observe the entry site but the tubing should be taped closely so that it cannot work in and out of the skin as the limb is moved. A sterile compress is then centered over the minute entry puncture by tape diagonally securing its corners. The adaptor is inserted into the free end of the tubing and taped loosely to the skin at a convenient point. A folded compress is placed under the adaptor unit so that it will not press directly on skin. A short piece of tape with adherent side upward may be placed under the adaptor tape at this point, holding the adaptor securely but allowing it to be tipped up for injection, and facilitating renewal of the compress beneath if it becomes soiled with iodine in preparing the cap for injection. Finally, a large compress is taped over the installation as a whole to keep clothing from catching on it. If one corner of this compress is placed over the adaptor it provides a tab which may be turned back to expose it for each injection without disturbing the dressing.

*Prepared for this work by courtesy of Becton, Dickinson & Co.

After use for several days the tube should be withdrawn and a different site intubated. (The tubing is discarded rather than cleaned, a boon to the nursing staff.) Alternating injections between simultaneously placed tubes is illogical, for then neither region used is truly rested from the solution, and it has been found that use of single areas with periodic relocation gives excellent results even with unusually large doses. Reinstallation every four days saves the patient thirty-one out of the thirty-two punctures otherwise required, and the remaining puncture (for the intubation) is made at the doctor's convenience with novocain. Patients may be ambulatory while undergoing discontinuous injections, and may move far more freely during a clysis technique than if stiff needles were used.

Grateful acknowledgments are due Miss Balbina Johnson of Surgical Bacteriology for sterility tests and for valuable suggestions; to the Departments of Medicine and Otolaryngology for clinical trials (Dr. T. Hunter and Dr. R. Robertson), and to the staff of the Babies Hospital.

STUDIES ON THE MECHANISM OF CITRATE INTOXICATION IN MASSIVE TRANSFUSIONS OF WHOLE BLOOD

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THE recent widespread practice of administering large amounts of citrated whole blood and plasma in the prevention and treatment of shock represents a major advance in the surgical care of patients. Investigative work in this field has resulted in a warning issued against the too liberal use of citrated blood. Ivy and his co-workers[1] found that animals bled 45 to 65 per cent of their estimated blood volume died in 84 per cent of cases if no replacement was made. If citrated whole blood or plasma was given over a five-minute period to replace the loss, 50 and 70 per cent, respectively, of the dogs died. If heparinized plasma were used for replacement, only 6 per cent of the animals died. Ivy and his associates concluded that 1,500 to 2,500 c.c. of citrated whole blood or plasma given rapidly to a man weighing 70 kilograms might prove fatally toxic. Bruneau and Graham[2] reported experiments in which dogs were bled 10 per cent of the estimated blood volume and the blood then reinjected during a one-half hour period. The reinjected blood contained either 0.6 per cent sodium citrate or heparin; the hemorrhage and replacement were repeated until the animals died. The dogs receiving the citrated blood expired after an average of 9.25 hemorrhages, or approximately 92.5 per cent of the estimated blood volume, while the dogs receiving heparinized blood averaged 25.2 hemorrhages, or 252 per cent of the estimated blood volume before death occurred. It was obvious from these experiments that some other factor than sodium citrate contributed to the death of the animals, but citrated blood was much more deleterious than heparinized blood.

First we undertook experiments[3] similar to those reported by Ivy and associates.[1] We found, as he did, that citrated blood given rapidly to treat

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shock produced by hemorrhage resulted in the death of the animal. However, dogs could be bled as much as 60 per cent of the estimated blood volume, and survive, if the replacement by citrated whole blood was made over a period of twenty minutes or longer. Evidently the sodium citrate was detoxified and excreted fairly rapidly. When bleeding and transfusions were conducted simultaneously an average of 122 per cent of the estimated blood volume was exchanged during a period of seventy minutes before the animal expired. When the rate of bleeding and transfusion was less rapid, a larger volume was exchanged without reaction. We concluded that the time of administration determined whether a serious or fatal reaction would occur, and felt that transfusions were rarely, if ever, given at a rate likely to cause citrate reactions in man. Calcium gluconate was found to be very effective in preventing or alleviating citrate intoxication when very large doses of citrate had been administered during a short period of time.

METHODS AND RESULTS

In the present study we attempted to perform experiments somewhat similar to those reported by Bruneau and Graham.[2] We felt that it should be possible to bleed and transfuse a dog indefinitely, providing the blood loss was replaced simultaneously. We modified our experiments to this extent: instead of bleeding the animal a given amount, and then replacing the loss, we obtained 200 c.c. of whole blood from another dog to use as a reserve supply. This blood was infused into a femoral vein as we conducted bleeding from the opposite femoral artery. The blood removed from the femoral artery was added to the blood in the flask leading to the vein. At the conclusion of the experiment 200 c.c. of whole blood remained in the flask to the femoral vein. In this way we could bleed and transfuse dogs simultaneously; at any given moment the status of the circulating blood was theoretically the same as when the experiment began, since bleeding and replacement were approximated.

Three experiments were performed with heparin. The animal was anesthetized with ether, one femoral vein cannulated for infusion, and the opposite femoral artery cannulated for bleeding. For convenience, 100 c.c. units were withdrawn. Each 100 c.c. of blood was heparinized by withdrawing it into a flask containing 0.1 c.c. heparin* in 5 c.c. of saline solution. As the first 100 c.c. were withdrawn, 100 c.c. of heparinized blood from a donor was injected. For the remainder of the experiment, the animal's blood was merely heparinized and reinjected. Dog 63 weighed 8.8 kilograms. The estimated blood volume was 880 c.c. He was bled 8,800 c.c. and transfused this amount of heparinized whole blood in five and one-half hours. He was sacrificed in eight days. No ill effects were noted. Dog 66 weighed 9.2 kilograms and had an estimated blood volume of 920 c.c. He was bled and transfused 9,200 c.c. in one hour and fifty-one minutes. No ill effects were noted and he was used in a different series of experiments two weeks later. Dog 15 weighed 14.3 kilograms and had an estimated blood volume of 1,430 c.c. He was bled 14,300 c.c. and transfused with this amount of heparinized whole blood in fifty-seven minutes. No ill effects were noted during a period of observation of two weeks.

Three similar experiments were run with citrated blood. The bleeding and transfusion were conducted as in the heparin studies. Each 100 c.c. of blood was drawn into a flask containing 20 c.c. of sodium citrate† and 3 c.c. of calcium gluconate.‡ It was necessary to agitate the blood constantly to

*Lederle, 1 c.c. = 10 mg. heparin.
†U. S. Standard Products Company, 2½ per cent solution sodium citrate.
‡Sandoz, 20 per cent calcium gluconate.

prevent clotting after the calcium gluconate was added. The experiments could not have been attempted without the addition of calcium gluconate since the animals would have soon died of citrate intoxication. Dog 105 weighed 7.3 kilograms and had an estimated blood volume of 730 c.c. Over a two-hour period he was bled 7,300 c.c. and this was replaced simultaneously with citrated, gluconated whole blood. The animal died two hours after the experiment was finished. Dog 114 weighed 8.3 kilograms and had an estimated blood volume of 830 c.c. He was bled and transfused 8,300 c.c. and died one hour after the study was completed. Dog 158 weighed 6.0 kilograms and had an estimated blood volume of 600 c.c. He was bled and transfused 6,000 c.c. in sixty minutes. This animal died shortly after the infusion was complete. Autopsies on these dogs showed generalized edema. Dogs 105 and 158 had marked pulmonary edema and Dog 114 had about one liter of free fluid in the abdomen. The kidneys were not abnormal. If one takes into account the volume of the sodium citrate and calcium gluconate added to the blood in these animals they received 230 c.c. of fluid per kilogram added to the circulating blood. This was thought to have been the principal cause of death.

Therefore, three animals were anesthetized and infused with 230 c.c. of physiologic saline solution per kilogram. No bleeding was done. Dogs 694, 695, and 690 weighed 12.5, 9.5, and 13.6 kilograms, respectively, and received 2,875, 2,185 and 3,128 c.c. of saline, respectively, in sixty minutes. All the animals showed marked enlargement of the abdomen and two (Dogs 694 and 690) had large, watery evacuations of the bowel at the end of the experiment. The respirations became hindered by fluid in the lungs. One animal (Dog 694) died within twenty-four hours and showed ascites (1,000 c.c.) and extensive edema of the lungs. Dog 695 was sacrificed in twenty-four hours and had edema of the tissues, but no marked ascites or pulmonary edema. The kidneys were very pale and swollen. Dog 690 recovered and was not sacrificed.

DISCUSSION

The experiments with heparin demonstrate that a dog can tolerate a remarkable turnover of the blood. To accomplish this certain hazards such as the production of shock must be avoided. The animal will not tolerate indefinitely repeated small lowerings of blood pressure. This is demonstrated by the experiments of Bruneau and Graham.[2] Our work is subject to the criticism that the dog's blood was reinjected. We feel that blood from other animals would have been just as satisfactory, but it is no small problem to obtain the volumes of blood used in these studies. The experiments using citrated blood conclusively prove that some disturbing factor was at work. Ivy and Bruneau and their coworkers had demonstrated this previously. However, since calcium gluconate had been used in these animals to restore calcium ions, we felt that some other factor was at fault. It occurred to us that the dogs who had their blood volume depleted and replaced ten times with citrated blood received, in addition, 230 c.c. of fluid per kilogram during the course of the experiment. It seemed that this might be responsible for the edema and death of the animals. For that reason 230 c.c. of physiologic saline solution per kilogram were given to three animals. It is not surprising that only one dog died, since physiologic saline solution produces less alteration of the state of the blood than any other solution commonly used. Warthen[4] demonstrated this and found that 65 to 175 c.c. of 0.7 per cent NaCl per kilogram of body weight injected into dogs in thirty minutes caused no reaction. It seems likely, then, that death in the animals receiving citrated blood

protected with calcium gluconate was due to overloading the blood stream with resultant pulmonary edema.

One more study should be made. The blood of dogs undergoing the experiments just cited should be perfused through a frog's heart preparation to test the toxicity of citrated blood with and without calcium gluconate protection. These experiments were planned, but abandoned because of shortage of personnel.

SUMMARY AND CONCLUSIONS

1. If shock is avoided a dog's blood volume may be depleted by bleeding and replaced by transfusion as many as ten times, using heparinized blood, without ill effects.

2. Dogs usually die if the same procedure is carried out using citrated blood, even though calcium gluconate is added.

3. This is thought to be due to the overloading of the blood stream by the large volume of fluid used to convey the sodium citrate.

4. It seems unlikely that any of the reactions seen in laboratory experiments would occur in man, and one should not hesitate to give massive transfusions when indicated.

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A MODIFICATION OF THE GIUS-RACELY PORTABLE SUCTION APPARATUS

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MEDICAL CORPS, ARMY OF THE UNITED STATES

GENERAL

AT THIS station a variety of suction devices have been used to decompress the intestinal tract in patients with abdominal distention due to intestinal obstruction, of the mechanical or paralytic types. Two-bottle and three-bottle sets have been employed to remove gas and fluid from intubated patients, but these methods have been clumsy, inefficient, and troublesome to all concerned, including the patient. We sought a more efficient and practical mechanism, and were pleased to find an article by Gius and Racely,* describing a new portable suction apparatus in which suction is produced through their two-bottle system by using a single cylinder tire pump.

With their idea in mind, we set out to build a similar device, but substituting a smaller pump. A shuttle pump was employed to initiate suction

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*Gius, John A., and Racely, Clay A.: A New Portable Suction Apparatus for Use With the Miller-Abbott Tube, SURGERY **15**: 574, 1944.

and this proved to be easy to operate and remarkably efficient. We found this new device to be very satisfactory and it has been enthusiastically received by the medical and nursing staffs concerned.

DESCRIPTION OF THE APPARATUS AND ITS CONSTRUCTION

Two one-gallon bottles are inclosed in a light wooden box. On one side of the box, a "shuttle" pump is mounted with the handle on the outside and it is operated with an easy motion. The handle can be rocked to-and-fro with gentle

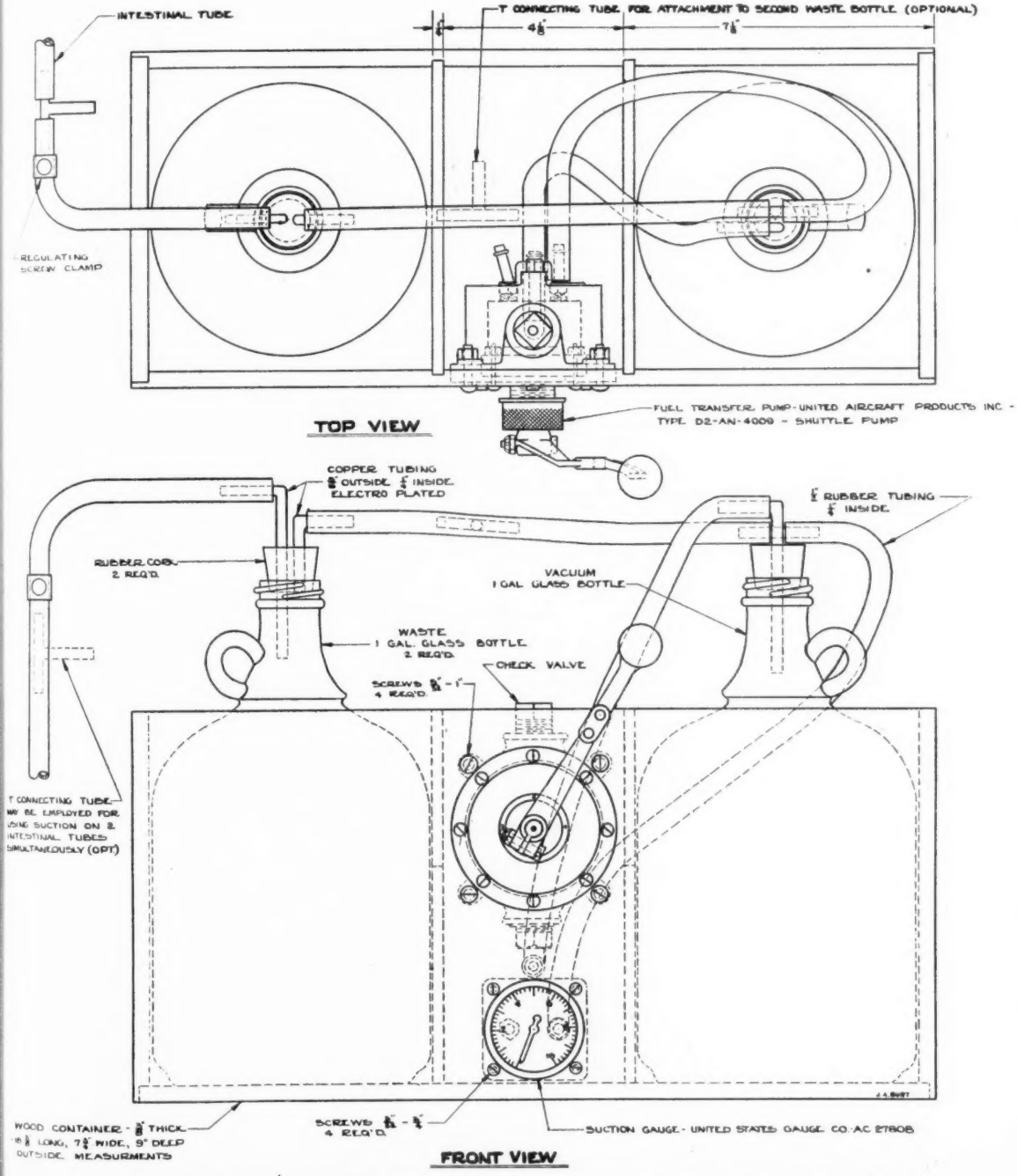
INTESTINAL TUBE
T CONNECTING TUBE FOR ATTACHMENT TO SECOND WASTE BOTTLE (OPTIONAL)
4⅜"
7⅛"
REGULATING SCREW CLAMP
FUEL TRANSFER PUMP - UNITED AIRCRAFT PRODUCTS INC. - TYPE D2-AN-4009 - SHUTTLE PUMP
TOP VIEW
COPPER TUBING ⅜" OUTSIDE, ¼" INSIDE, ELECTRO PLATED
RUBBER TUBING ¼" INSIDE
RUBBER CORK 2 REQ'D.
VACUUM 1 GAL GLASS BOTTLE
WASTE 1 GAL GLASS BOTTLE 2 REQ'D.
CHECK VALVE
SCREWS ⅜" - 1" 4 REQ'D.
T CONNECTING TUBE MAY BE EMPLOYED FOR USING SUCTION ON 2 INTESTINAL TUBES SIMULTANEOUSLY (OPT.)
WOOD CONTAINER - ⅝" THICK - 18½" LONG, 7⅞" WIDE, 9" DEEP OUTSIDE MEASURMENTS
SCREWS ⅜" - ¾" 4 REQ'D.
SUCTION GAUGE - UNITED STATES GAUGE CO. AC 27808
FRONT VIEW

Fig. 1.—Photograph of detailed drawing of portable suction apparatus showing front and top views. Note optional insertions of T tubes included to suggest possible use for decompression of two or more patients simultaneously. (Official Photograph by U. S. Army Air Corp.)

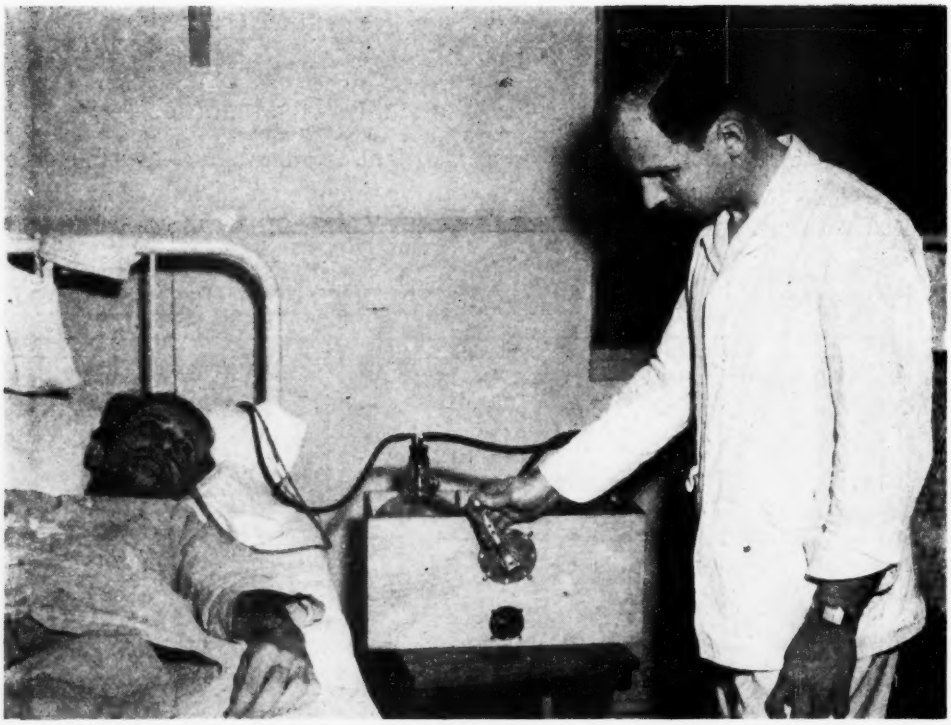

Fig. 2.—Apparatus in use on a patient with a paralytic ileus; Miller-Abbott tube is being used for intubation. (Official photograph by U. S. Army Air Corp.)

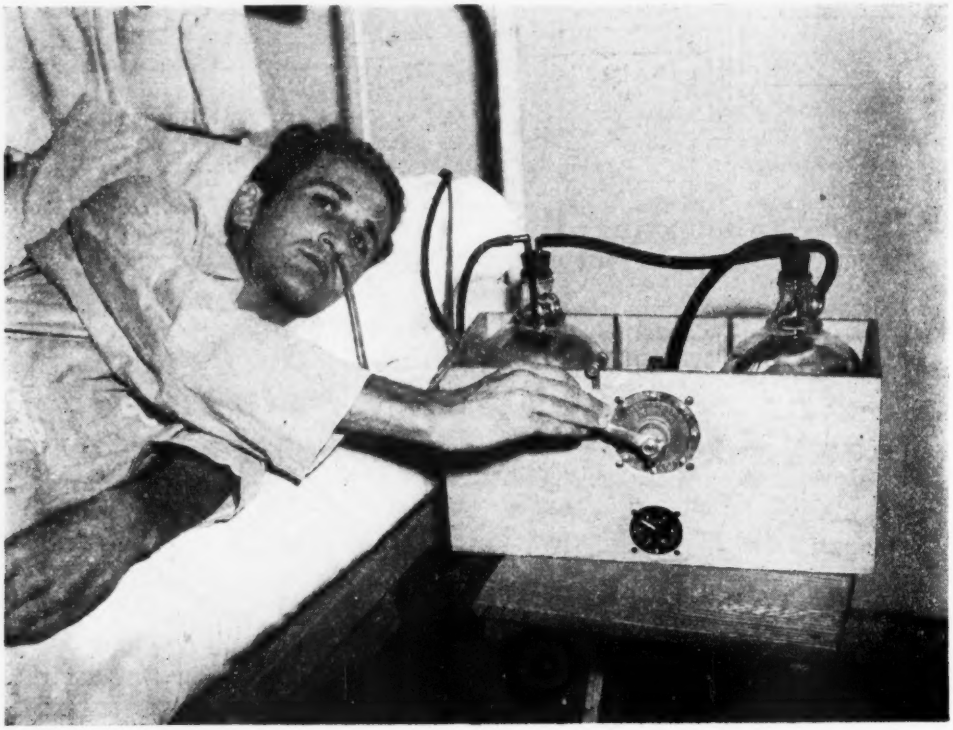

Fig. 3.—Same case as Fig. 2; the patient is demonstrating the ease with which the shuttle pump may be operated by all but the acutely ill. (Official photograph by U. S. Army Air Corp.)

pressure between the thumb and index finger of either hand. The two bottles are connected with each other by rubber tubing through two two-hole rubber stoppers with tube connectors. In our set, three right angle and one T-tube connectors are used. The intestinal tube is connected to the waste bottle, the pump being connected to the vacuum bottle by means of similar tubing and connections. A manometer giving the negative pressure reading within the system is connected to the vacuum bottle. Operation of the pump removes the air from the system and suction is produced on the intestinal tube through its attachment to the waste bottle. This bottle acts as a reservoir for the gaseous and fluid contents to be removed. (See Figs. 1 to 4.)

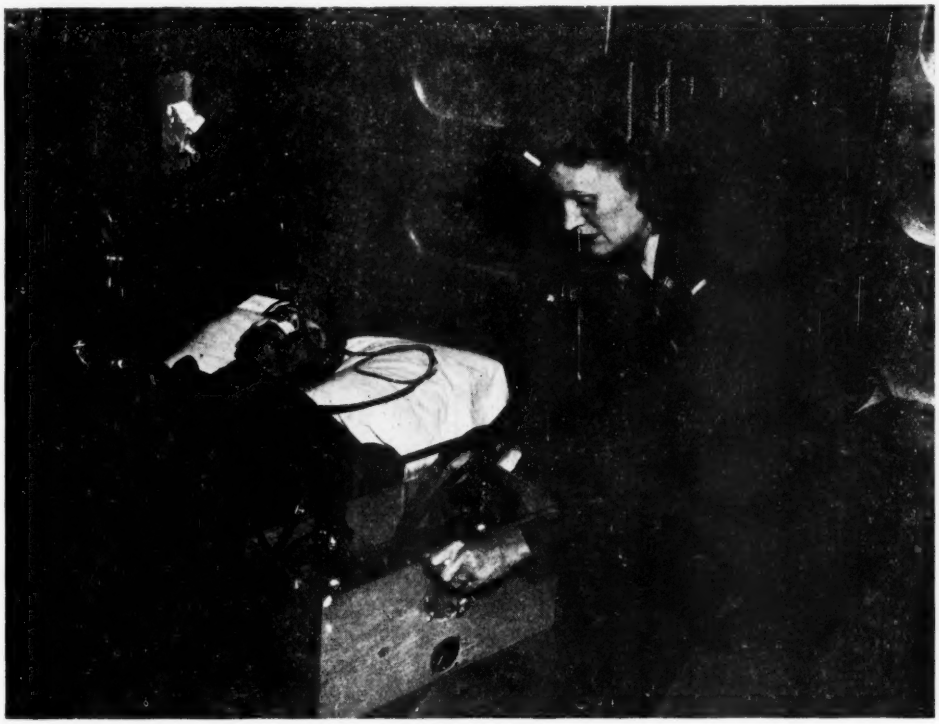

Fig. 4.—Photograph made inside a hospital airplane showing proposed use in air evacuation of the wounded. (Official photograph by U. S. Army Air Corp.)

OPERATION OF THE APPARATUS

The suction device may be placed beside the patient's bed, on a table or a chair. Preferably it should be one to two feet lower than the body, to develop a siphon effect, but it can be operated at the same level as the patient without the aid of gravity. Before operating the shuttle pump to create suction in the system, the intestinal tube should be clamped off to eliminate any possible damage to the gastrointestinal mucosa by sudden change in pressure in the openings in the end of the tube. We have found that an effective negative pressure range with this machine is two to four inches of mercury (50.8 to 101.6 mm.). Less suction is required to produce evacuation of gastrointestinal contents through a single lumen tube, such as the Levin tube, than through the use of the double-lumen Miller-Abbott tube, the latter being longer and of smaller diameter. Two to three inches (mercury) of negative pressure (50.8 to 76.2 mm.) are adequate for the single-lumen tube and three to four inches (76.2 to 101.6 mm.) are satisfactory for the double lumen tube. Once the desired amount of negative pressure has been created in the bottles, as shown

on the gauge, the intestinal tube can be opened and the rate of drainage regulated as desired, by means of a screw clamp. We have found that when the negative pressure has been lowered to four inches (101.6 mm.) of mercury, 950 c.c. of fluid, or an equivalent amount of gas, will be evacuated, when the base of the suction device is level with the tip of the suction tube. With the base of the device twenty inches below the level of the tube tip, a siphon effect is obtained and 1,300 c.c. of fluid will be delivered into the waste bottle.

The first device that we constructed had no provision for preventing back leakage of air through the pump, with a fairly rapid loss of negative pressure and consequent loss of suction. This was prevented by clamping off the tube from the pump to the vacuum bottle after operation of the pump. Its operation was somewhat complicated, but this disadvantage was minimized on a subsequent model by placing a check valve on the outlet valve of the pump. Thus, back leakage into the bottles was prevented when the apparatus was in use.

SUMMARY

A suction device for gastrointestinal decompression has been described. It is an efficient, easily operated mechanism, which may be transported with the ease of a small handbag from ward to ward, in the hospital. It weighs 12¾ pounds. The parts required for construction should be available at any Army Air Force installation. It is primarily for use in cases of gastric and/or intestinal distention due to paralytic ileus or intestinal obstruction of the mechanical type. It also has been used effectively for pharyngeal suction after applying an appropriate suction tip. We feel that it would be ideal for use in air evacuation on patients requiring continuous suction, due to the fact that it is so compact and efficient. This apparatus may be used to decompress several patients simultaneously by inserting T-tube connectors at the appropriate sites (see Fig. 1).

The device described is a modification of the suction apparatus described by Gius and Racely, and we acknowledge the stimulation which it provided in the construction of our machine. We feel that the pressure gauge and the shuttle pump are a decided improvement and though they add expense in construction, promote efficiency in operation.

The authors wish to express appreciation to Major J. M. Lynch, M.A.C., who arranged for the construction of the apparatus and to Harry E. Hill and Joseph P. Quinn who built the machine. Drawings of the apparatus were made by Joseph A. Burt. Photographs were made by Lieutenant Cala G. Harrison, Base Photographic Officer.

SPICULAR FOREIGN BODIES IN ESOPHAGUS

Report of Three Unusual Cases

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ELONGATED pointed foreign bodies, such as pins, needles, and bones, especially fish bones, are frequently encountered at the base of the tongue, in the tonsillar regions, and in the hypopharynx but seldom in the esophagus. When meat, however, is attached to a fragment of bone, it often lodges in the esophagus. Unless a foreign body which is thought to be spicular in shape can be visualized when the entire pharynx is examined, the opinion may be expressed that the object has passed into the stomach and that the residual symptoms are emotional in origin.

The exact location of a metallic foreign body can be determined by roentgenoscopic examination, but errors may occur in that a patient may think he has ingested a metallic foreign body when actually he has swallowed something that is nonopaque to roentgen rays. Fragments of bone that lodge in the esophagus are usually found just below the cricopharyngeal constrictor muscle and may be identified in a lateral roentgenogram. Bones are not demonstrable when roentgenograms are made with the patient in an anteroposterior position. Calcification of laryngeal cartilages or of other structures in the cervical region may be mistaken for intraesophageal foreign bodies and frequently foreign bodies may be overlooked on roentgenoscopic examination.

In the majority of cases of suspected foreign body in the esophagus, direct inspection should be made through an esophagoscope, for this is the most accurate and the safest method of diagnosis and treatment. Passing stomach tubes into the esophagus or advising a patient to eat corn bread or bread crusts in an effort to dislodge a foreign body are procedures that date back to an era less enlightened than our present day. Of course, there are neurotic persons who have many sensations that persist in the throat for months or years. These patients should be treated kindly and sympathetically but usually should not be examined with an esophagoscope. However, when symptoms suggesting a foreign body have been present for less than one week, esophagoscopic investigation is usually indicated.

When the presence of any type of foreign body is suspected in the esophagus, a mixture containing barium should not be ingested to facilitate roentgenoscopic study. Iodized oil is preferable for this purpose, since it will not obscure a foreign body nor will it interfere with immediate esophagoscopic examination.

CASE REPORTS

Case 1.—An edentulous man, 50 years of age, was examined Nov. 20, 1942. Six years previously, while eating chicken, he thought he swallowed a bone. Symptoms persisted and two days later a physician passed a stomach tube, with apparent dislodgment of the foreign body. Six hours after passage of the tube, pain developed in the left side of the thorax and there was moderate elevation in temperature. Although the patient was not confined to bed, he felt bad for at least one month.

Recovery was then apparently complete for eighteen months, when fever again developed and he coughed up a moderate amount of blood and foul-tasting pus. Following this episode he had continuous cough, which was usually nonproductive save for once or twice a

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month, when he expectorated a small amount of pus and blood for one or two days. Prior to evacuation of this secretion, he had mild elevation in temperature. Administration of sulfonamide drugs seemed to hasten recovery from these exacerbations.

For one year or more previous to our examination, the patient had noted painful swollen joints, and this symptom was intensified during the periods of fever. When the accumulated secretion in the bronchi drained, he felt better in every way. Repeated roentgenoscopic and physical examinations of the thorax had not revealed a significant lesion (Fig. 1). The first bronchoscopic study of the patient disclosed nothing abnormal.

During the next two years the patient was examined repeatedly, and on six occasions bronchoscopic investigation was performed. At five of these examinations a small amount of

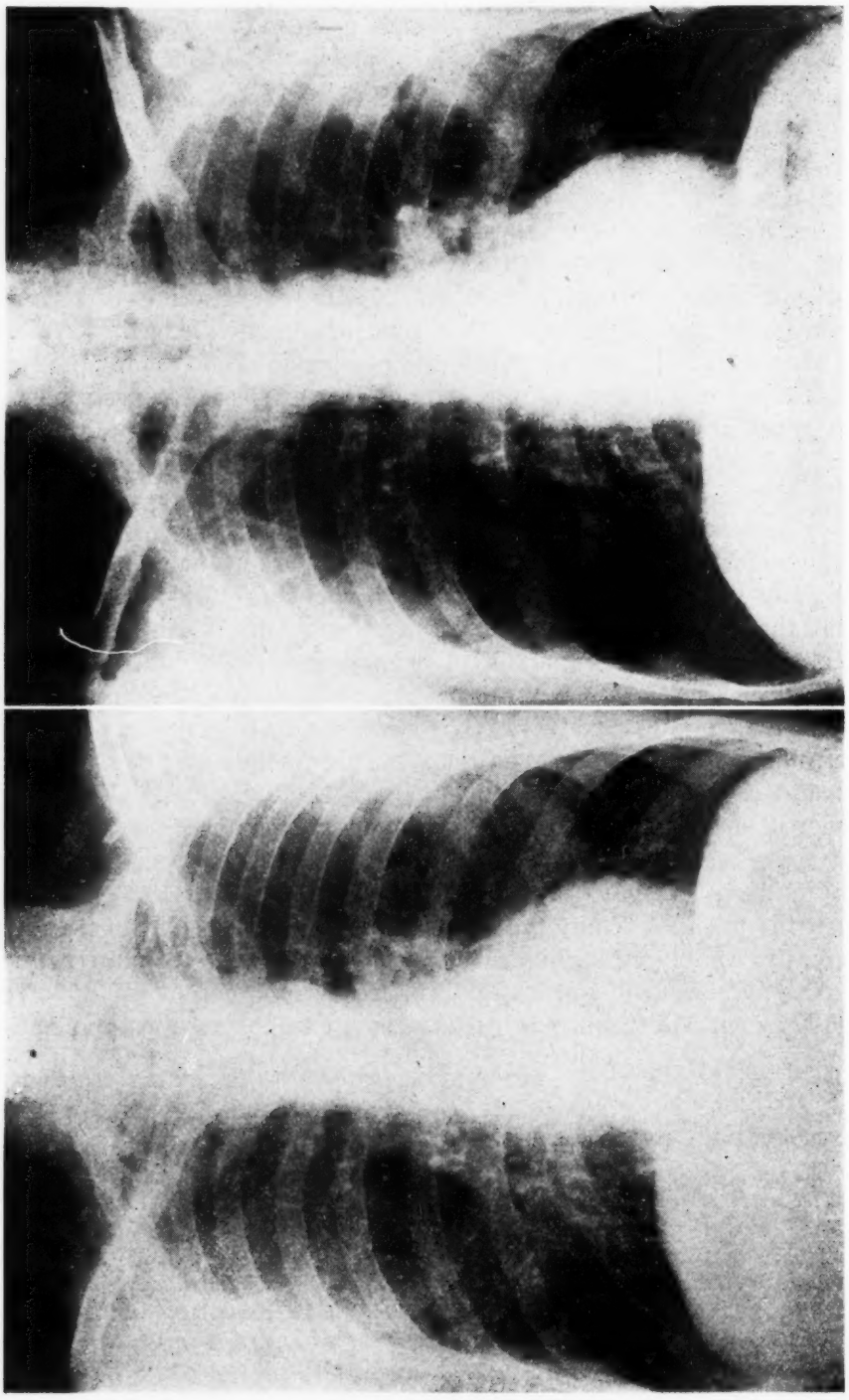

Fig. 1 (Case 1). Normal thorax.
Fig. 2 (Case 1).—Area of infiltration at periphery of left lung, with small cavity partly filled with fluid.

pus was found in the left main bronchus, and twice a tiny bit of blood was encountered, but no definite lesion was seen.

Sept. 21, 1944, when the patient returned for further study, he had had a more prolonged period of fever than usual, with expectoration of a larger amount of pus and blood than previously. A roentgenogram made at this time revealed an area of infiltration at the periphery of the left lung, with a small cavity partly filled with fluid (Fig. 2).

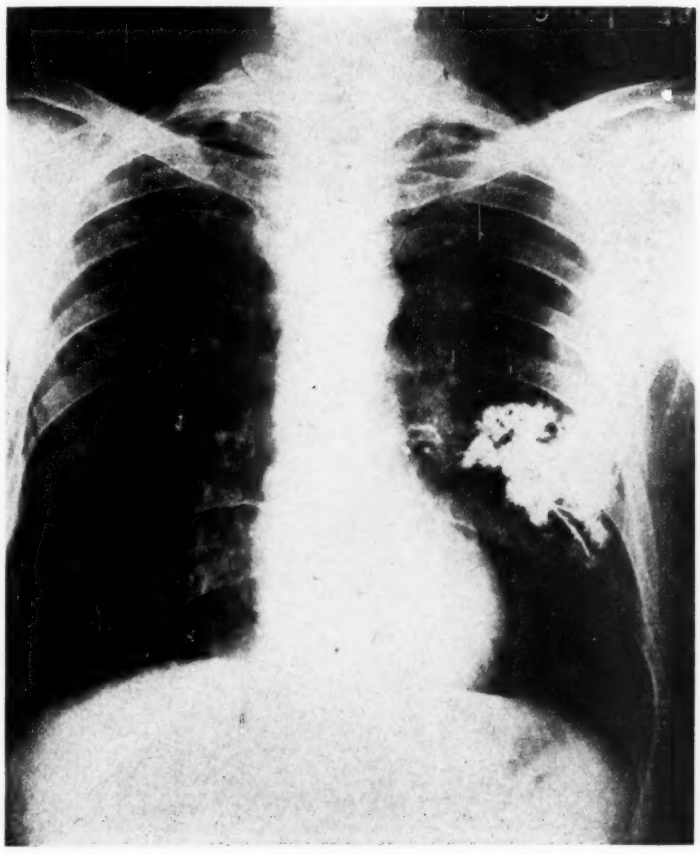

Fig. 3 (Case 1).—Iodized oil showing filling of cavity.

Fig. 4 (Case 1).—Spicule of bone removed surgically from left lung.

Bronchoscopic study then revealed pus and blood coming from the inferior division of the bronchus to the upper lobe of the left lung. Iodized oil was injected into this bronchial division, and a roentgenogram showed filling of the cavity (Fig. 3). Surgical drainage of the cavity was recommended, and at the time of operation a spicule of bone was found within the cavity and was removed (Fig. 4). The patient recovered completely and has remained well.

CASE 2.—A woman, 67 years of age, was admitted to Riverside Hospital, Newport News, Va., Sept. 7, 1944. Her chief complaint was severe lower substernal pain that had begun five days previously while she was eating an ordinary meal. The onset of pain was not associated with the sensation that a foreign body had been swallowed. The pain persisted and was

followed by elevation in temperature to 102° F. Just prior to being admitted to the hospital, she vomited a large blood clot.

Occlusion of one of the coronary arteries was suspected, but an electrocardiogram showed normal tracings. General physical examination revealed nothing significant pathologically, save that many teeth were absent and that the twelve that remained were loose and infected. Various laboratory studies showed normal findings, with a leucocyte count of 12,000. Twenty-four hours after admission, the patient suddenly died.

Post-mortem examination revealed a straight fish bone one inch in length which had perforated the wall of the upper portion of the esophagus and had entered the aorta, with fatal hemorrhage into the gastrointestinal tract (Fig. 5). On questioning her relatives after the bone was found, it was ascertained that at the onset of her illness the patient was not eating food that contained bones and that she had not eaten fish within one week of the beginning of her difficulty.

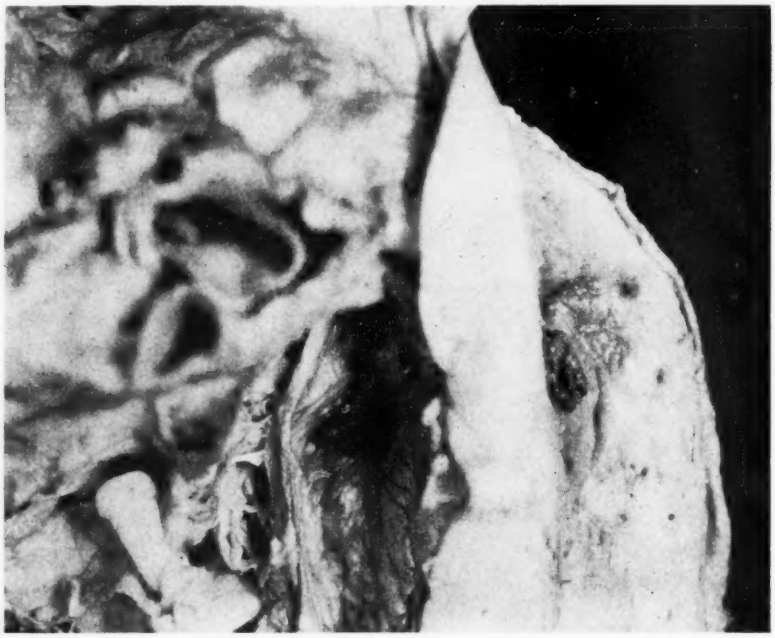

Fig. 5 (Case 2).—Fish bone, one inch in length, found at autopsy to have perforated the esophagus and aorta.

CASE 3.—A woman, 35 years of age, was examined March 7, 1945. She said that she had been well until December, 1943, when she had begun to lose a little weight. She had not consulted a physician until May, 1944, when nothing was found on physical examination to explain the loss of weight and she was merely advised to give up her work and take a prolonged vacation. She stopped working June 30, 1944. Three days later, July 3, 1944, while eating a piece of chicken, a pain suddenly developed in the right side of her throat. She was unable to swallow saliva without intensification of the discomfort and she had pain in the right shoulder and fever. These symptoms gradually subsided, and after ten days she was able to swallow solid food without a feeling of obstruction but with continued associated pain.

One month later she had a coughing spell, with evacuation of a moderate amount of foul-smelling bad-tasting pus and blood. These episodes of drainage occurred several times, and after each evacuation of pus and blood, she remained free of symptoms for several weeks. She had irregular elevation of temperature, depending on the adequacy or inadequacy of drainage from the lung. Roentgenograms revealed an area of density in the apical area of the right lung. Treatment consisted of administration of penicillin for two weeks during the latter part of August and the first part of September, 1944.

The patient's normal weight of 138 pounds had dropped to 110 during the acute illness, but at the time of our examination it was 143 pounds. The only significant findings at the time of our general physical examination of the patient were a partial upper dental plate and evidence of an impaired percussion note at the apex of the right lung anteriorly. Further

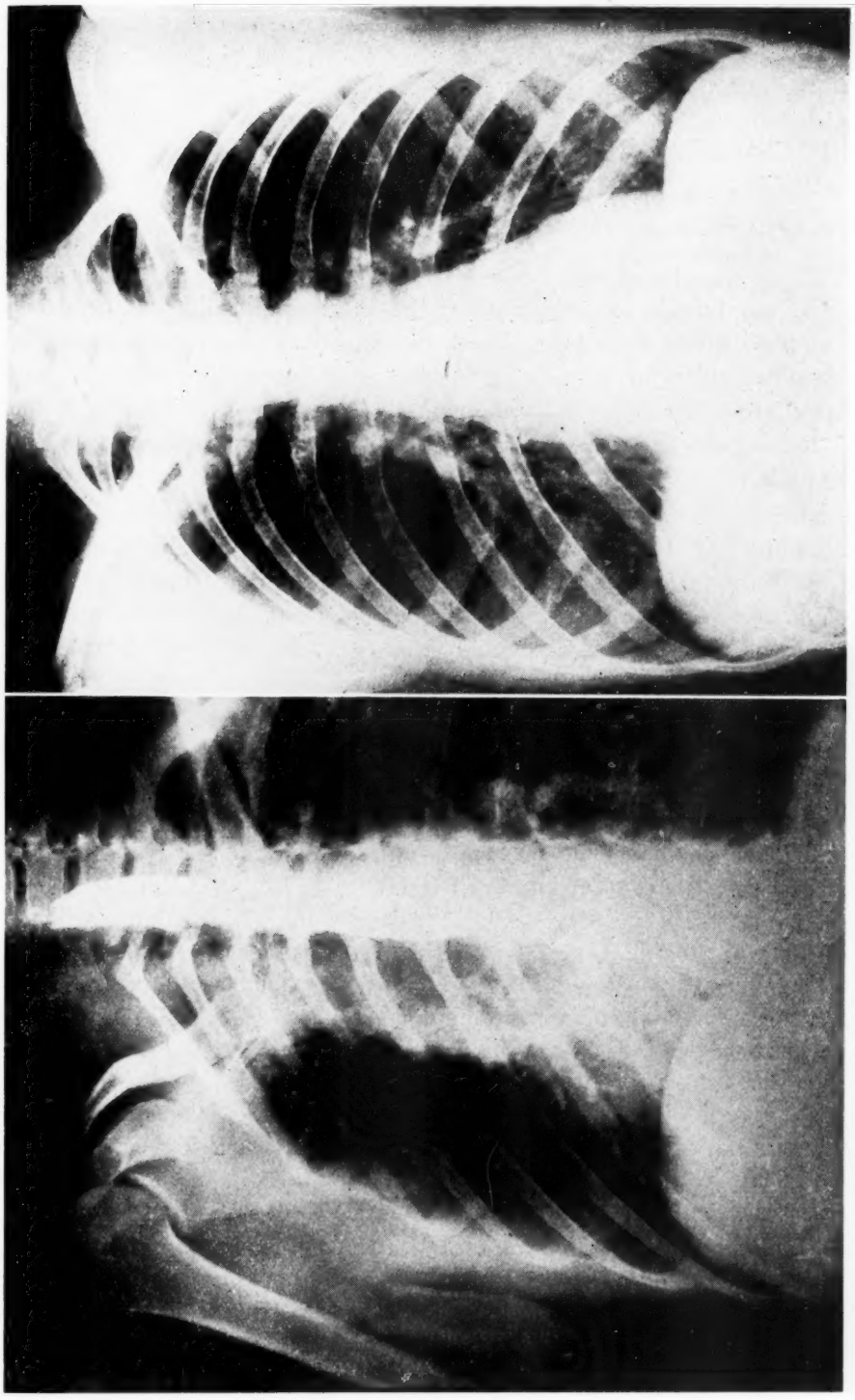

Fig. 6 (Case 3).—Defect on right wall of upper esophagus, representing probable exit of bone.
Fig. 7 (Case 3).—Elongated shadow, apparently a bone, in right lung.

roentgenoscopic studies revealed a defect on the right wall of the upper portion of the esophagus, which probably represented the exit of the bone from the esophagus (Fig. 6). In line with this defect, presumably in the tissue of the right lung, was an elongated shadow, which was apparently a bone (Fig. 7).

The previously mentioned area was explored surgically without recovering the bone, but a small cavity communicating with a bronchus was encountered and drained. If symptoms recur, an effort will be made to remove the foreign body with a bronchoscope. At this writing, the patient looks and feels well and the thoracotomy is healing satisfactorily.

THE SURGICAL PROBLEM OF CANCER IN LYMPH NODES

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OF THE two routes of wide cancer dissemination, lymphatic and hematogenous, the lymphatic is clinically the more important. Cancer cells, because of their invasive tendency, break into capillary lymphatic channels and may grow along them for varying distances. Such lymphatic permeation probably takes place to some extent in all tumors which metastasize by way of these vessels. Retrograde extension from a secondary focus, such as a lymph node, may take place in like manner.

Junction of forward permeating cells from a primary tumor and of backward extending cells from an involved node area may occasionally take place in cases of marked advancement. Initial node involvement by progressive permeation from a primary site of disease to a normally distant node group must be a very rare incident. The only possible means of surgically coping with such situations is by uninterrupted excision in continuity of both the primary tumor and its draining node area. The prognosis in cases really requiring such extensive procedures will be extremely poor.

The more usual means of spread, however, once lymphatic invasion about a primary tumor has occurred, is by a breaking-off process of fragments of the tumor which then become lymphatic emboli. How long an interval is required for such emboli to travel from primary lesion to node is a matter for conjecture. Considerable variation probably exists. If India ink (particulate carbon) is introduced within lymphatics it may be found in the nodes seconds later.[14] On the other hand, melanotic nodules may subsequently make their appearance in the lymphatics of an extremity in which two weeks or more have been permitted to elapse between primary excision and node dissection (Fig. 1). The size of the particle, cell, or cell cluster, as well as the velocity of the lymph stream, very likely has considerable influence on the speed with which the lymphatics are traversed and these clusters, if large enough, may therefore become arrested along their course. The afferent lymphatics enter the cortical sinus of a node where microscopic tumor emboli then first appear.

The old hypothesis that the hyperplastic changes in lymph nodes draining an area in which a tumor resides represent a reaction against metastases similar to that presented against bacterial toxins finds no substantiation. Lymph nodes appear to offer fertile soil to metastatic tumor growth and, when involved, render the prognosis distinctly worse than when involvement is not present. On the other hand, the nodes do act as interrupters in the dissemination process and it can be conceded that without them lymphatic invasion would add but another brief step to hematogenous spread.

This function of the regional lymph nodes is now generally recognized. Clinical demonstration of node involvement, it is unanimously agreed, should be dealt with by en bloc removal of the node groups apart from certain contraindications to be considered later. Considerable controversy exists regarding the

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proper method of dealing with draining node areas in which there is no clinically demonstrable metastatic disease. Some prefer to adopt a policy of watchful waiting, relying on careful follow-up to dictate subsequent procedure, carrying out node dissection only if or when disease appears in these structures. Proponents of this policy argue that needless dissections are thereby avoided, the chief importance of which lies in the fact that these operations carry a varying but definite operative mortality. Opposed to this group are others who contend that prophylactic dissection should be carried out whenever one is dealing with a tumor of known metastasizing potentialities, although there is little agreement among them as to what extremes such action should be carried. It might be well to digress at this point in order to establish definitions.

Fig. 1.—Primary melanoma of skin of dorsum of foot, excised elsewhere three years previously. Two years later nodules were noted along the leg and thigh (circled). These were recently treated by combined excision of a wide strip of skin between the primary site and inguinal region and radical groin dissection.

Therapeutic dissection is generally intended to convey the idea that the size and character of the nodes have led to a preoperative supposition of clinical involvement. Prophylactic dissection implies that the nodes are suspected of containing disease despite the absence of physical signs indicating involvement. Since the distinguishing signs are entirely clinical, it is apparent that in both instances errors in diagnosis will occur which in percentage figures will vary not only with the type of tumor under consideration, but also with the skill and experience of the examiner. It is hardly possible to evaluate such a factor but its presence should be remembered. The proponents of prophylactic dissections argue that careful follow-up is subject to many uncertainties and quite cor-

rectly insist that the treatment of cancer in lymph nodes, as elsewhere, offers the best results when carried out as early as possible.

It is the purpose of this paper to examine the problem of node treatment from its several aspects in an attempt to determine how such treatment may be developed to maximum advantage.

NODE INCIDENCE: FACTORS RELATING CHIEFLY TO THE PRIMARY TUMOR

There is a well-recognized and wide variation in the frequency with which different tumors metastasize to lymph nodes (Table I). These variations are

TABLE I. NODE INCIDENCE IN SOME OF THE COMMONER TUMORS

TUMOR	PER CENT
Carcinoma, intrinsic larynx[16]	10
Carcinoma, skin[18]	12 to 15
Carcinoma, penis[18]	25
Carcinoma, lip[13]	31
Carcinoma, lower gingiva[3]	35
Carcinoma, buccal mucosa[3]	40
Carcinoma, vulva[19]	46
Carcinoma, tongue and floor of mouth[9, 12]	63
Melanoma, skin[4]	64
Carcinoma, rectum*[8]	68
Carcinoma, colon*[1]	70
Carcinoma, extrinsic larynx[16]	70
Carcinoma, stomach*[2]	75
Carcinoma, breast*[17]	75
Carcinoma, tonsil[11]	77
Carcinoma, nasopharynx[10]	80

*Only cases in which operation was done.

dependent on a number of factors which are partly anatomic and partly inherent in the primary tumor. Different sites of primary involvement appear to present varying degrees of resistance to local spread, and quantitative differences in the lymphatic system of the part alter the accessibility of invading cells to the node channels. Carcinomas of the intrinsic and extrinsic larynx often exemplify this quite well. Extension of a primary tumor from its original site to involve adjacent structures having their own lymphatic network will also exert definite influence. Morphologic differences of tumors of the same part are well-known factors, that is to say, whether the tumor is of adenoid or epidermal origin. This is particularly true of the carcinomas of the hard palate. Within these separate groups there also reside differences concerned with the degree of anaplasia of the tumor. Many of the reasons for the peculiarly varied manifestations of these groups and subgroups are not well understood and must await further enlightenment, but the differences are nonetheless present. In certain groups of tumors, activity inherent in grading follows rather consistently. Epidermal tumors are good examples. In others inconsistencies occur so commonly as to render any rule unworkable (notably adenocarcinomas of the breast). Other factors include the size of the lesion, whether the tumor is primary or recurrent, the nature of previous treatment, and the duration of symptoms.

Another consideration not discussed in the literature but which seems to be pertinent to the present problem relates to quantitative node involvement in dissection specimens from the various tumors and the relative frequency with which widespread metastases occur (Table II). It should certainly seem reasonable that if a tumor of a given description metastasizes with considerable regularity to only one or two nodes, remains confined there after all clinical doubt as to its presence has been dispelled, and very rarely kills by reason of more widespread dissemination, then such a tumor might as well be treated by

TABLE II. THE EXTENT OF NODE INVOLVEMENT IN POSITIVE DISSECTION SPECIMENS

SITE OF PRIMARY INVOLVEMENT	NUMBER OF CASES	AVERAGE NUMBER NODES INVOLVED	PER CENT WITH MORE THAN ONE INVOLVED NODE
Epidermoid carcinoma of skin	19	1.9	35
Carcinoma, penis, vulva, anus; bilateral dissections	6	1.8 (?)	50 (?)
Oral cavity (tongue, floor of mouth, buccal mucosa)	15	2.3	47
Carcinoma of lip	34	2.7	53
Melanoma of skin	22	2.6	60
Carcinoma of colon and rectum	33	3.3	60
Carcinoma of breast	100	6.1	79

a dissection done therapeutically as prophylactically. Conversely, when a tumor regularly metastasizes to local nodes before its presence becomes clinically appreciable, is found to involve numerous nodes of specimens examined, and not infrequently brings about death by distant spread, such a dissection must be carried out prophylactically if it is to be of any use at all. In fact, more prophylactic and fewer therapeutic dissections in such situations would in all likelihood save the most lives. More will be said of this later. It is not implied that such an appraisal can always be accurately made. Exceptions will occur but many tumors fortunately follow a fairly set pattern and if an attempt is made to understand this their behavior may be predicted with considerable accuracy. It thus becomes apparent that the problem is concerned not only with how frequently regional nodes are involved but also with how rapidly the disease is apt to spread beyond the limits of the removable chain.

NODE REMOVAL: SURGICAL CONSIDERATIONS

In many instances the anatomy may be so adaptable that removal of the primary tumor with the regional nodes becomes little more of a task than removal of the primary alone. This is true of the stomach, bowel, lung, etc. Consequently, in these there can be no question as to whether or not prophylactic dissection should be carried out, regardless of considerations such as the incidence of node involvement or the inaccessibility of the regional nodes to subsequent examination.

A closely analogous situation is presented in carcinoma of the breast. Ignoring for a moment other highly important factors, simple mastectomy with subsequent decision as to axillary dissection might well enter into the discussion were it not for the anatomic fact that clean dissection from the costoclavicular ligament to the latissimus dorsi muscle, bearing in mind the lymphatic drainage of the breast, necessitates removal of the pectoral muscles, all of which may be performed better and more efficiently on initial exposure by way of radical mastectomy. The question of node dissection, therefore, pertains mainly to those tumors in which the primary and node area are best treated separately either at one sitting or in stages. (Table III.)

Consideration must be given to the relative satisfactoriness of the several major dissections—cervical, axillary, and inguinal—based on the anatomy peculiar to each. The neck in general lends itself very well to node dissection. If the jugular vein and sternomastoid muscle are removed one finds the nodes encased in well-defined surrounding structure. In addition, a considerable length of distal lymphatic chain is removable since the clinical involvement is usually present in the submaxillary or subdigastric node areas. Axillary dissections done primarily for malignant tumors of the skin (not breast cancer) with lymphatic

TABLE III. REASON FOR NODE DISSECTIONS WITH REFERENCE TO THE PRIMARY SITE IN 160 PATIENTS

PRIMARY SITE	NUMBER OF PATIENTS	NODES POSITIVE
Melanoma, skin	34	24
Carcinoma, lip	44	35
Carcinoma, skin	25	20
Carcinoma, lower gingiva	12	1
Carcinoma, buccal mucosa	10	6
Carcinoma, tongue	7	5
Carcinoma, penis	6	2
Carcinoma, vulva	4	2
Carcinoma, anus	4	1
Carcinoma, miscellaneous	15	12
Total	161	108 (67%)

drainage to that node area, although less satisfactory than cervical dissections, nevertheless can be done with considerable satisfaction providing the arm is placed in a position to relax the pectoralis major and the scapular attachment of the pectoralis minor is divided. Radical groin dissection, however, is a rather unsatisfactory procedure from the standpoint of cancer surgery and the margin of safety is therefore narrower when involvement is present. The inguinal and femoral node groups may easily be removed with a protecting zone of tissue but the obturator and iliac nodes lie encased in a variable amount of friable fat and poorly defined areolar tissue. It would, therefore, seem reasonable to perform groin dissection with less weight of indication than might be considered necessary for the performance of neck dissection. The relative effectiveness of axillary and groin dissections is undoubtedly one of the factors involved in the poorer end results obtained in melanomas and skin cancers involving the lower extremity as compared to those involving the upper extremity or face and neck. A similar factor is probably operative in determining the poorer prognosis of carcinoma of the stomach as compared to carcinoma of the colon since the paragastric nodes are not anywhere near so neatly accessible as those draining the colon.

Not infrequently it happens that additional information gained in treating the primary tumor renders the prognosis so much poorer than was originally calculated that further treatment seems futile. Following a Miles resection for a carcinoma of the anus, for example, a pathologic report of extensive hemorrhoidal node involvement, as well as nerve and blood vessel invasion, would be sufficient evidence to discourage doing bilateral radical dissections on groins which appeared to be clinically uninvolved. Similarly, a neck dissection could hardly be expected to improve results in a cancer of the oral cavity which had stubbornly shown no inclination to yield to treatment. One might continue along this vein in the presentation of other factors which, however, pertain more to specific tumors or instances.

So far, no mention has been made of "routine prophylactic dissection," although this term is frequently encountered in the literature. It need hardly be stated that no one treating any considerable number of patients of the cancer age group will be able to perform node dissection routinely. The mortality in node dissections is not high, probably in the neighborhood of 5 per cent when

TABLE IV. REGIONAL NODE DISSECTIONS ACCOMPLISHED AS SEPARATE PROCEDURES

REGION	NUMBER	POSTOPERATIVE DEATHS
Neck (subtotal and total)*	124	10
Axilla	17	0
Groin	48	0

*Combined mandibular resection done in thirty patients.

appraising the entire heterogeneous group (Table IV). When applied to a certain poor-risk subgroup, however, it will become prohibitive. This must be borne in mind when comparative end result figures are stated to show the advantage of prophylactic dissection, for in choosing such a group a selection of patients more likely to survive a five-year period is automatically made.

To date, there appears to be little convincing factual evidence presented either for or against these prophylactic procedures. There can be little argument that cancer in lymph nodes is best treated while still in its subclinical stage. It is also true that only harm in needless operative mortality will result from operation in any group of patients whose nodes have repeatedly been demonstrated to be negative. The suspicion of metastatic nodal disease cannot be based on possibilities, for with cancer anything is possible; it must be founded on presumptive evidence. The quixotic attitude of radical advocates of prophylactic dissections will discredit such operations. Adopting the two previously mentioned principles, it then is no longer a question of whether one does or does not subscribe to prophylactic dissections for tumors of a certain organ or structure; rather, it becomes a matter of deciding which patient will require such a procedure. That decision can be arrived at only when all of the available facts pertaining to the individual case are known and weighed in understanding of the life history of the particular kind of tumor present and of its therapeutic setting. It is conceded that all such evaluations will not subsequently be proved correct, yet no surgeon today would advocate routine gastric resection for all cases of peptic ulcer, although it is conceded that fatal hemorrhages and fatal perforations will, with conservative management, occur occasionally in the hands of the most experienced clinician. The exception cannot establish the rule.

Certain definite contraindications to separate node dissection, either prophylactic or therapeutic, will readily be accepted as absolute and should require no further discussion:

(1) an uncontrolled or uncontrollable primary tumor; (2) distant metastases; (3) extremely poor general condition.

Three additional and frequently mentioned contraindications to node dissection must be considered relative rather than absolute: (1) perforation of the node capsule by disease as evidence by fixation or demonstrable invasion of adjacent structures such as skin or bone; (2) bilateral or contralateral node involvement; (3) highly undifferentiated tumors.

Exceptions to the first of the relative contraindications should include instances in which the disease has been of a low grade of malignancy and has shown a disposition to progress only locally in nodes which are still amenable to wide surgical removal. Carcinoma metastatic from the lip to the submaxillary nodes which may invade the mandible and skin provides an excellent example (Fig. 2). Under such or similar circumstances it has been the policy at this hospital to remove any involved structures which are not definitely vital to the patient.

It is less simple to outline exceptions to the second mentioned relative contraindication. In general, this one will stand when an evaluation of all factors concerned points to a very aggressive form of disease. Factors such as a less than highly differentiated (grade II to IV) primary tumor in a normally unfavorable site and/or disease present bilaterally simultaneously with a short history are exemplary. Under such circumstances there seems little doubt but that the very occasional cured lesion would be many times outweighed by the operative mortality. Especially would this be true of bilateral neck dissection with bilateral

internal jugular ligation. Carcinoma of the lip here also presents the greatest number of noteworthy exceptions (Fig. 3). Martin and associates[13] reported 20 per cent of patients with bilaterally positive nodes surviving five years. Our own experience with such patients has also been encouraging to date.

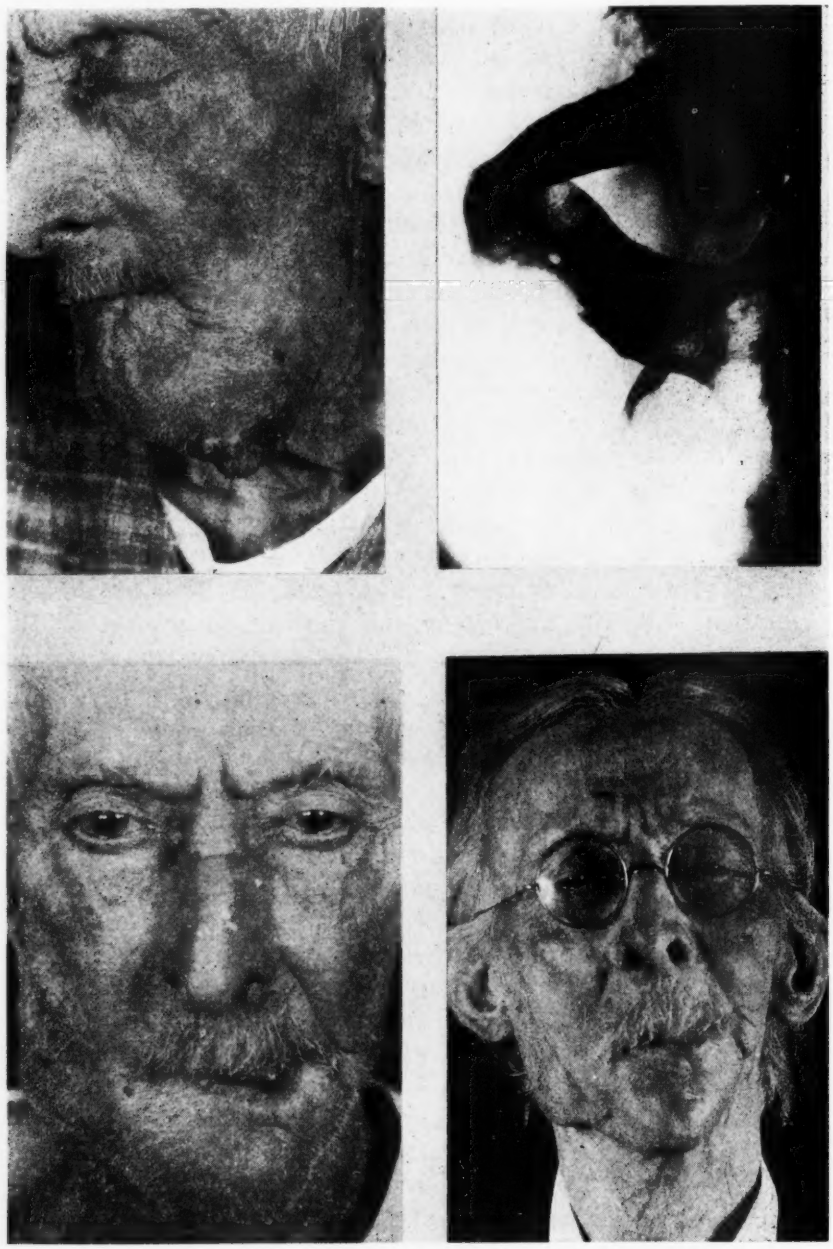

Fig. 2.—Carcinoma metastatic to the left submaxillary lymph nodes (primary tumor of lip treated elsewhere) with ulceration through the skin and invasion of the mandible; treatment was combined jaw resection-neck dissection. Later contralateral metastases developed; treatment was supra-omohyoid neck dissection.

Highly undifferentiated tumors to which belong the majority of the carcinomas of the nasopharynx, base of the tongue, pharynx, extrinsic larynx, etc., are primarily radiotherapeutic problems because of their general radiosensitivity. In addition, metastases when they occur tend to be widespread. However, occasionally one of these is encountered in which the primary tumor has completely disappeared under treatment but the nodes have not. In the absence of any

demonstrable distant spread their removal seems to be justified as offering the only remaining chance of cure.

That surgery occupies a place in the treatment of lymphosarcoma was demonstrated in a review by Sugarbaker and Craver[15] of 196 biopsied cases. Twenty-four patients had been treated by operative node removal which had

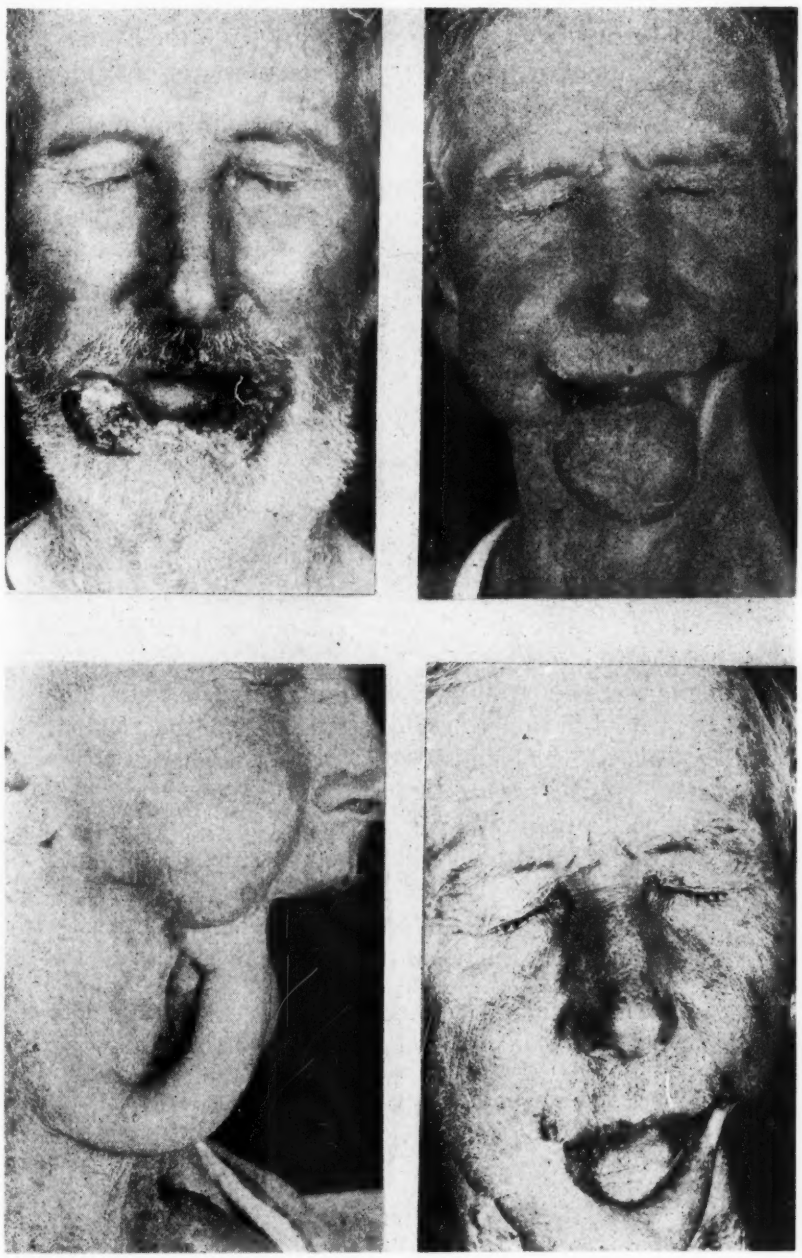

Fig. 3.—Advanced carcinoma of the lower lip fixed to the mandible and metastatic to submaxillary and submental node areas bilaterally. Treated by block resection of lip and mandible with bilateral supraomohyoid neck dissection and showing subsequent reconstruction.

usually been followed by postoperative x-ray. Six of these remained well without return of disease for five or more years. Although the number so treated was small, the results in that group were more encouraging than those derived from any other form of treatment. It is probable that patients under 30 years of age, in whom the disease is usually very active, and those with disease in more than one node area, regardless of age, should be rejected for node dissection in

lymphosarcoma. Similarly favorable results from surgery in this condition have since been reported by Gall.[7]

Practicality does not here permit a discussion of the problem as it separately relates to several of the individual tumor groups nor would this be possible since comparable figures are rarely available. It might be well to consider them, however, as they pertain to one group in which reliable data is present and over which considerable controversy has arisen—carcinoma of the lip.

Arguments proposing prophylactic dissection in cancer of the lip:

1. Eleven to twelve per cent of patients with clinically negative nodes have disease contained in them.
2. The economy of doing needless dissections cannot be computed against the life of those who survive only because they have had dissections done.
3. The operative mortality for upper neck dissections should not be more than 1 to 2 per cent.
4. Some patients will fail in their follow-up and will therefore lose their chance for cure.
5. Of patients prophylactically dissected and having pathologically positive nodes, 42 per cent[5] survive five years.

Arguments opposing prophylactic dissection in cancer of the lip:

1. About 11 to 12 per cent[13] of patients with negative nodes on admission will develop them later.
2. Therefore, approximately nine out of ten neck dissections will be done needlessly.
3. The operative mortality from clinics treating large numbers of patients has varied in upper neck dissections from 0.42 per cent[6] to 6.9 per cent.[5] This will undoubtedly be somewhat higher in the hands of surgeons doing only an occasional operation.
4. With good organization, a follow-up of 95 per cent[13] may be attained and needed dissections may then be done as soon as nodes develop.
5. Thirty-seven per cent of patients having dissections done for nodes developing during follow-up survived five years.[13]

In consequence it would seem proper to review several factors known to influence the incidence of node metastasis in carcinoma of the lip.

1. Whether the lesion has been previously treated. Figi[6] found positive nodes in only 4.5 per cent of all "primarily" treated patients whereas they were present in 17 per cent of all patients whose lesions were "secondarily" treated.
2. The grade of the primary. Taylor and Nathanson[18] recorded a node incidence of 6 per cent in Grade I lesions, 30 per cent in Grade II, and 52 per cent in Grade III. Figi[6] found no metastases in any Grade I "primarily" treated case.
3. The size of the primary. Martin and associates[13] in a large series of cases have stressed this and reported a rising incidence with increasing size of the lesions in patients whose nodes were negative on admission from 3 per cent with lesions until 1 cm., to 10 per cent with lesions 1.0 to 1.9 cm., to 13 per cent with lesions 2.0 to 2.9 cm., to 26 per cent with lesions over 3 cm. in diameter.

It therefore appears reasonable, in carcinoma of the lip, to direct the effort of prophylactic removal for occult cancer only to those patients in whom sufficient indication exists, for only by this means will the number of operative deaths be reduced in patients whose nodes are later found to be uninvolved.

Attention should be called to the wide difference in five-year end results existing between patients with lip cancer who present nodes on admission (24 per cent, Martin and associates[13]) and those who develop them later (37 per cent, Martin and associates[13]) or are found to have them on prophylactic dissection (39 to 42 per cent, Figi,[6] Eckert and Petry[5]). Allowing for a small number of patients with nodes who present hopelessly advanced disease at the time of admission, this amounts to about 15 per cent. The greater aggressiveness of the disease or late arrival of the patients for treatment is the logical explanation for this difference in survival but more important are the therapeutic implications since suprahyoid or supraomohyoid neck dissections are quite generally considered to be adequate treatment for cervical metastases from lip carcinoma. We have very carefully examined thirty consecutive dissection specimens in sixteen of which nodes were clinically positive on admission and in fourteen of which they were clinically negative but were found either on prophylactic dissection or had developed during follow-up. In the sixteen cases (nodes positive on admission) the average number of nodes involved was 3.4, and nine had more than 2 nodes involved. Among the fourteen cases (nodes negative on admission) the average number of nodes involved was 1.3 and in no case were more than 2 nodes involved. We have made a similar study in melanoma often clearing the specimens in order that the greatest possible number of nodes might be found and sectioning each node. Parenthetically it should be said that no attempt is being made to draw any general comparison between cancer of the lip and melanoma. It should be pointed out, however, that whereas no surgeon would do less than the most radical node dissection either prophylactically or therapeutically for melanoma, the quantitative node involvement per specimen was less than in the sixteen patients with lip cancer whose nodes were present on admission. Of thirteen consecutive dissection specimens in which at least one positive node was found, the average number of nodes involved was 2.8. Such a high quantitative node involvement in lip cancer in which the nodes are already present on admission and particularly when they are confined to one side of the neck should probably be met by radical neck dissection reserving the less radical procedures for prophylactic or later therapeutic dissection in which such procedures seem to be safe.

In the surgery of cancer there are, in general, two major problems which frequently demand careful consideration: first, the degree of radicalness required by the tumor and second, the degree of radicalness which the patient will withstand. Overestimation of the first and underestimation of the second will result in too high a percentage of postoperative fatalities. The converse will result in too low a percentage of cured cases. Adequate attention is usually paid to careful estimation of the patient, but experience gained at a tumor clinic from referred cases teaches that more emphasis should be placed on an estimation of his tumor, particularly as it pertains to the node status, and no decision as to the extent of the procedure required should be reached until every means of determining that status has been dealt with short of interfering with the execution of whatever procedures may be contemplated.

The declaration as to whether a dissection is being done prophylactically or therapeutically is based entirely on clinical findings. The correctness of the

original assumption is determined only when the specimen is carefully examined in the laboratory. That this assumption is frequently proved to be incorrect in the prophylatically dissected group has been amply illustrated. Neither is it unusual to dissect for what are taken to be involved nodes only to find that hyperplasia alone is present. This is particularly apt to occur when the primary tumor is badly infected. In the interests of more precise evaluation and more balanced treatment, such mistakes in diagnosis should be eliminated in so far as is possible. The employment of aspiration biopsy for suspected nodes will be of great aid in problems of such therapeutic importance. There is little need to elaborate further in this regard except to state that the material obtained from metastatic lymph nodes by this simple procedure, if similarly treated, is no more difficult to interpret microscopically than that obtained by incisional biopsy and is equally reliable since negative material by whatever means obtained, either by incision or aspiration, may be meaningless. The arguments propounded against this procedure are reminiscent of those formerly voiced against the biopsy of surface lesions and are equally theoretical. In our experience aspiration biopsy of suspected lymph nodes has been a valuable clinical aid and in the absence of unfortunate sequelae places the burden of proof of theoretical concepts directly on critics of the procedure.

SUMMARY

1. The role of the lymphatic vessels and nodes in cancer dissemination is briefly discussed.

2. It appears remarkable that prevailing opinions regarding the treatment of occult cancer in lymph nodes should remain so divergent.

3. In an attempt to shed some light on the question the factors relating to the incidence of node metastases and to node removal are reviewed.

4. The arguments for and against prophylactic node dissection are examined as they pertain to carcinoma of the lip, since comparable and reliable figures are at present available for this group alone.

5. When the results of each method of treatment are examined, it is found that the anticipated greater survival among those prophylactically dissected and having involved nodes (as compared to those dissected after the nodes have been permitted to become clinically apparent) is overbalanced by a greater number of operative deaths most of which occurred in patients whose nodes were found on pathologic study to be uninvolved.

6. Such unnecessary deaths can largely be eliminated by more careful attention to factors predisposing to node metastases reserving dissection for those in whom such factors are prominent.

7. It is further suggested that patients having carcinoma of the lip and arriving for treatment with nodes already present in the neck be given the benefit of total neck dissection whenever possible since on specimen study they are found to have approximately three times as many involved nodes as those who develop the nodes after the primary tumor has been treated or are found to have involved nodes on prophylactic dissection. It is felt that upper neck dissections have largely contributed to the poorer prognosis of the first mentioned group and should be reserved for patients who are prophylactically dissected or whose nodes develop while under close observation.

8. The employment of aspiration biopsy will be of great diagnostic aid in making such distinctions.

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EFFECT OF TOTAL THYROIDECTOMY ON EXPERIMENTAL PRODUCTION OF PEPTIC ULCER

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AMONG the generally accepted factors in the etiology of peptic ulcer, two stand out in bold relief, namely, hyperacidity and nervous tension.

Heretofore most of the regimens that have been devised for the treatment of peptic ulcer have been based principally on control of acidity of the gastric secretion. Regarding surgical treatment, gastrojejunostomy was once the procedure of choice. Later, pyloroplasty occupied that position and this in turn has been succeeded by partial gastrectomy. The fact remains that the ideal method of management is not as yet at hand. How can one escape the feeling that the sacrifice of the greater part of a normal stomach is a very high price to pay for the cure of an ulcer of small dimensions?

The practice of physicians of securing sedation of patients suffering from peptic ulcer by the use of various drugs represents an attempt to control the second etiologic factor, that is, nervous tension. Unfortunately, only too often

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the nervous mechanism of such patients fails to slow down appreciably. Is there anything else that one could do to curtail some of that drive which is so characteristically abundant?

As lethargy is a striking feature in myxedema, total thyroidectomy suggests itself as a means of swinging the pendulum in that direction. Will such a surgical procedure have the desired effect on peptic ulcer? This experimental study was undertaken to answer precisely that question.

MATERIALS AND METHODS OF STUDY

A series of five experiments was performed. Healthy adult dogs were used. They were maintained on a standard kennel diet except for the first three days following surgical duodenal drainage when a 5 per cent solution of dextrose in physiologic saline solution was administered by the intravenous route. All the operations were performed with the animals under ether anesthesia and with aseptic technique. Body weights were obtained at intervals of about two weeks following total thyroidectomy and every three days to one week after the performance of the Mann and Williamson[1] operation.

The total thyroidectomy was carried out through a midline incision in the neck. Great care was exercised in searching for the superior parathyroid glands and leaving them in situ with an intact blood supply. No attempt was made to preserve the inferior parathyroid glands.

Mann and Williamson's surgical procedure was used to produce peptic ulcer. The jejunum was divided 10 to 15 cm. beyond the ligament of Treitz. The proximal end was anastomosed obliquely to the side of the ileum about 60 cm. above the ileocecal junction. The pylorus was divided and the duodenal stump was closed and inverted. The continuity of the gastrointestinal tract was restored by an end-to-end anastomosis between the stomach and the distal end of the divided jejunum. All the anastomoses were made by means of an inner row of a continuous suture of plain No. 1 catgut for the mucosa and an outer row of interrupted fine silk sutures for the seromuscular layers.

RESULTS

The effects of total thyroidectomy in this series of experiments were consistently the same. All the dogs lost an appreciable amount of their original vigor, suggesting the presence of varying degrees of lethargy. Their hair became coarse, brittle, and sparse and their skin dry and thickened. The composite picture seemed to provide an experimental counterpart of myxedema as seen in man.

The most striking sequel of total thyroidectomy was an increase of body weight varying from 1.1 to 6.5 kg. (Fig. 1). The increments represented 8, 21, 22, 33, and 37 per cent of the original body weights of the five dogs. For example, one dog weighing 17.5 kg. at the time of operation gained as much as 6.5 kg. over a period of seventy-four days (Table I).

TABLE I. ACTUAL AND PERCENTAGE GAIN OF BODY WEIGHT AFTER TOTAL THYROIDECTOMY

EXPERIMENT	INITIAL WEIGHT (KG.)	MAXIMAL WEIGHT (KG.)	GAIN OF BODY WEIGHT	
			ABSOLUTE (KG.)	PER CENT OF INITIAL WEIGHT
I	17.5	24.0	6.5	37
II	13.2	14.3	1.1	8
III	12.0	14.5	2.5	21
IV	10.5	14.0	3.5	33
V	10.0	12.2	2.2	22

TABLE II. ACTUAL AND PERCENTAGE LOSS OF BODY WEIGHT AFTER SURGICAL DUODENAL DRAINAGE

EXPERIMENT	MAXIMAL WEIGHT (KG.)	TERMINAL WEIGHT (KG.)	LOSS OF BODY WEIGHT		
			ABSOLUTE (KG.)	PER CENT OF MAXIMAL WEIGHT	PER CENT OF INITIAL WEIGHT
I	24.0	10.7	13.3	55	76
II	14.3	8.8	5.5	38	42
III	14.5	8.7	5.8	40	48
IV	14.0	7.6	6.4	46	61
V	12.2	6.8	5.4	44	54

The dogs were observed for forty-nine, sixty-one, sixty-one, seventy-three, and seventy-four days before the Mann and Williamson operation was performed. At the time of exploration, a peptic ulcer had not developed in any case.

Following the institution of surgical duodenal drainage, the body weight declined rapidly in each case (Fig. 1). On the basis of the maximal body

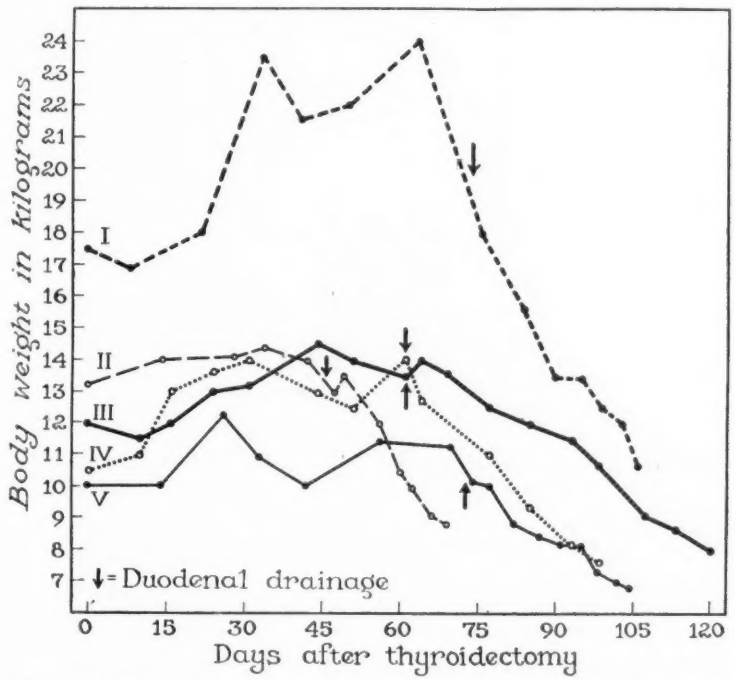

Fig. 1.—Changes of body weight after total thyroidectomy and after surgical duodenal drainage.

weight before this operation, the losses were 5.5, 5.8, 5.4, 6.4, and 13.3 kg., representing 38, 40, 44, 46, and 55 per cent of the maximal body weights of the five dogs. When the initial body weight at the time of total thyroidectomy was taken as the standard, the losses amounted to as high a percentage as 42, 48, 54, 61, and 76 (Table II).

TABLE III. SUMMARY OF STUDY AND RESULTS

EXPERIMENT	PERIOD FROM TOTAL THYROIDECTOMY TO DUODENAL DRAINAGE* (DAYS)	PERIOD OF SURVIVAL AFTER DUODENAL DRAINAGE (DAYS)	DIMENSIONS OF ULCER† (CM.)
I	74	34	2.8 × 1.8 × 0.6
II	49	28	2.0 × 1.5 × 0.6
III	61	62	2.5 × 2.1 × 1.5
IV	61	43	2.6 × 1.4 × 0.8
V	73	34	2.2 × 2.2 × 1.2

*At the end of this period there was no evidence of peptic ulcer in any case.
†A bleeding perforating chronic peptic ulcer was observed at necropsy in each case.

The dogs survived twenty-eight, thirty-four, thirty-four, forty-three, and sixty-two days following the Mann and Williamson operation. At necropsy, a chronic peptic ulcer with punched out margins and an indurated base was invariably found (Fig. 2 and Table III). It was located characteristically on the superior posterior wall of the jejunum immediately beyond the pyloric ring. Its size varied from 2.0 by 1.5 cm. to 2.5 by 2.1 cm. The shallowest ulcers were 0.6 cm. deep, while the greatest depth was 1.5 cm. The immediate

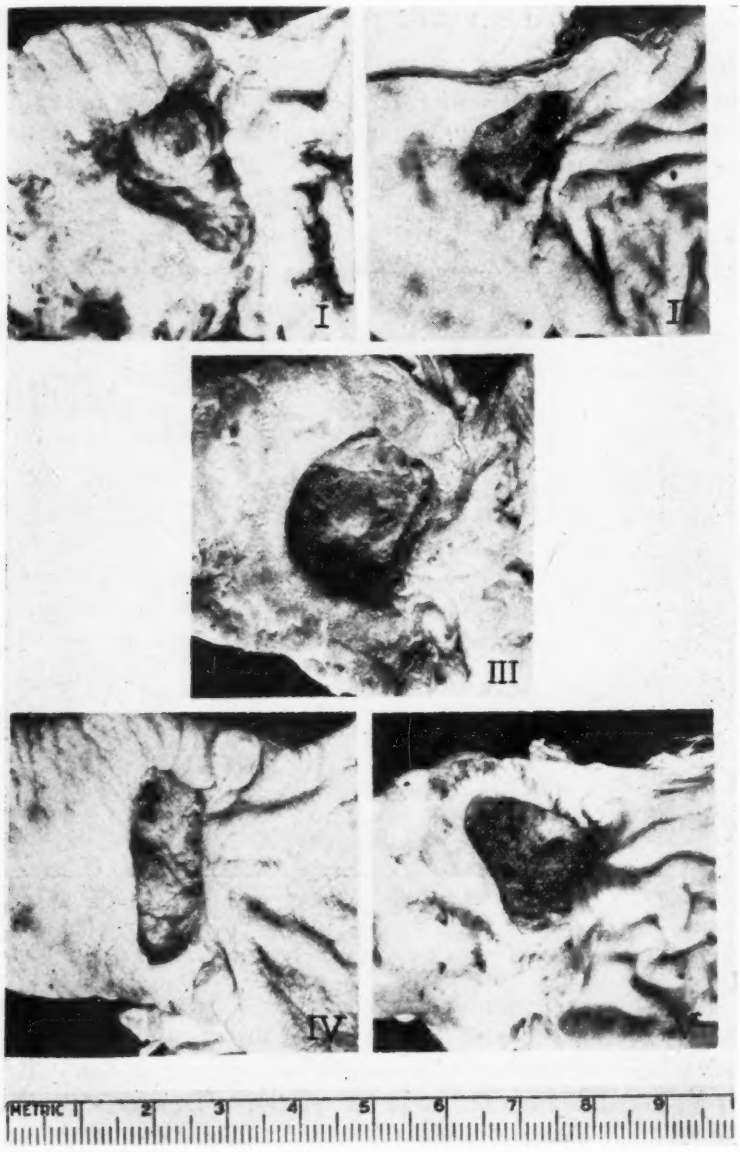

Fig. 2.—Peptic ulcers produced by surgical duodenal drainage after total thyroidectomy.

cause of death of all the dogs was a massive hemorrhage from an eroded blood vessel at the base of the ulcer. In some instances, it appeared as if perforation would have occurred had not the base of the ulcer been supported by the contiguous duodenal stump or liver to which it was adherent.

COMMENT

Experimental hypothyroidism is known to produce a decided increase in volume of gastric juice and a less marked, but nevertheless demonstrable, in-

crease of acidity.[2] For this reason, the dogs in this series of experiments were observed for a period varying from forty-nine to seventy-four days following total thyroidectomy but before duodenal drainage. It is interesting that in no case did a gastric or duodenal ulcer develop.

On the other hand, total thyroidectomy does seem to modify the character of the peptic ulcer resulting from the employment of the Mann and Williamson operation. As compared with my observations in other studies,[3, 4] the ulcers are definitely more chronic, the craters being larger and deeper, and the period of survival of the dog is longer. One is tempted to speculate whether the differences might not be due in a large measure to the excessive body weight resulting from total thyroidectomy. Mann has pointed out to me, however, that the absolute and percentage loss of body weight in this series of experiments not only is greater, but also occurs more rapidly than usual.[5]

Against this background of experimental evidence, it seems difficult to understand the basis of the clinical observation that, in dealing with a patient who suffers concomitantly from hyperthyroidism and a peptic ulcer, subtotal thyroidectomy often ameliorates the symptoms due to the ulcer. However, one must admit that the abolition of hyperthyroidism does not necessarily mean the installation of a hypothyroid state. In other words, there is a rather wide range of normalcy in the activity of the thyroid gland.

The results of this study indirectly lend emphasis to gastric acidity as being the most important factor in the pathogenesis of peptic ulcer. Total thyroidectomy, although it leaves lethargy in its wake, has nothing to recommend it as a therapeutic measure for the disease.

SUMMARY AND CONCLUSION

Total thyroidectomy was performed on five dogs. No peptic ulcer developed after forty-nine to seventy-four days. Following the use of Mann and Williamson's operation to establish surgical duodenal drainage, a chronic peptic ulcer developed in all of the dogs after twenty-eight to sixty-two days. The conclusion is that total thyroidectomy does not have any mitigating effect on the experimental production of peptic ulcer.

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THE HEALING OF ARTERIES AND THE RELATIONSHIP TO SECONDARY HEMORRHAGE

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IN EARLIER experiments on repair of arteries with the use of heparin, Payr's clips were used. Later modifications of these, a small tube with a right-angled flange, were made. These methods were obviously designed to eliminate the necessity of suturing vessels and, probably what was more important, would eliminate the multiple injuries of intima at the site of suture as well as the presence of foreign body at the suture line. It was found in the course of the experiments that these aforementioned objections were of no significance when heparin was used as an anticoagulant to overcome these ill effects, namely, thrombosis at the suture line. The control of these difficulties has been described in earlier publications.[1] An interesting side line which developed out of these experiments is worthy of consideration, especially at the present time with war surgery in the forefront and with blood vessel injuries and surgery being practiced daily following war wounds. The points which we would like to consider are:

1. The effect of rigid metal or other material when applied as a circumference around an artery as demonstrated in Payr's clips and more recently in the Blakemore[2] tubes, etc.
2. The possible relationship of secondary hemorrhage to the effect produced by such a constricting band, or a ligature, and what method might be used as an alternative to prevent these complications.
3. The question of the survival of a venous graft bridging a gap in an artery applied in an infected field, such as a war wound.

In the earlier experiences in arteries with the clips already mentioned applied on the carotid arteries of dogs, it was found that excellent union of the vessel would occur but all the animals died of hemorrhage from the carotid artery within a period of two to six weeks. On studying these specimens, it was demonstrated that the hemorrhage occurred from a blowout of the artery immediately adjacent to the site of application of the rigid metal band. When this particular area was examined more closely, it was demonstrated that there appeared to be necrosis of the artery wall for a short distance (a few millimeters) proximal to the edge of the metal band. This appeared to have developed and to have softened so that somewhere in the third, fourth, or fifth week, the vessel gave way under the arterial pressure. On a theoretical basis, it appeared that possibly the resistance of the rigid band against the arterial pressure within the lumen was sufficient to cut off the vascular supply to the wall of the vessel through the vasa vasorum with the resulting necrosis and ultimate giving way of the wall.

It was on this evidence that it was decided that sewing up of the vessels with a suture might give better results than would the application of metal bands, etc.; our experience in many hundreds of experiments has proved this to

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be true. On no occasion has the suture line shown necrosis even when applied at each end of a venous graft. These suture lines and grafts have not blown out and, as described in earlier publications,[3] the only problem in these cases was the question of thrombosis at the suture lines which was prevented by the use of heparin.

On giving further consideration to these secondary hemorrhagic effects, following ligation of vessels, the literature was reviewed to determine the end results of ligation of the aorta in human beings. There is a multitude of methods described to occlude the aorta and this, in itself, was some evidence that no single method was entirely satisfactory. In the recorded cases with few exceptions, where the human aortae were occluded by ligatures, fascial bands, tapes of various sorts, and metal bands of wires, all the patients died of secondary hemorrhage within a period of a few months to one year, except in those cases dealt with by a graft described by Reid,[3] in which a foreign body such as a ball of fascia or other material was inserted in the lumen of the aorta proximal to the site of literature or occlusion. The effect of this latter method was obviously to produce a fairly large area of thrombosis and clotting, proximal to the suture line, thereby protecting it and any area of necrosis that might ensue, during the following weeks or months.

These observations seem further to support the point already made that a rigid constricting band of any sort around a major vessel may cause an area of necrosis at the site of its application.

Obviously in smaller vessels or in vessels containing a larger proportion of muscle in the wall, the results of ligation are uniformly good except perhaps in the presence of infection. This possibly may be accounted for by the fact that ligation of any of these muscular vessels causes extreme vasoconstriction which in itself would be a protective mechanism and would favor more extensive thrombosis and clotting in the region of the ligature.

With this evidence in mind, experiments were done on the aortae of dogs. In a control group, the aorta was tied off and divided between ligatures. Various forms of ligatures were used. We were aware, however, that the abdominal aorta in a dog is not as important an arterial supply to the areas distal as is that in a human being, because of the many large branches through which collateral anastomosis, and so on, takes place. For that reason the vessel in itself is comparatively smaller and more muscular than the human aorta at a similar level.

None of these vessels exploded so that the control of the experiment was not as satisfactory as had been hoped.

In many groups of animals, instead of the aorta being tied off after it was divided, the ends were sewn up neatly with arterial suture in a fashion similar to that used in anastomosis or repair of arteries, with better end results in healing.

Obviously, if the main arterial supply and, therefore, the nutrition of the periphery is cut down by war wounds of a major vessel, the natural defense barriers to infection are greatly weakened and, thereby, the growth of organisms and invasion of tissue by infection is greatly increased. It seemed, therefore, that with injury to a main artery of an extremity, one of the best methods of obviating amputation and of preserving tissue and eliminating or reducing disabling infections in the affected extremity might be provided by a restoration of the arterial supply to the part. It would seem, then, that even in the presence of an infected wound (as are all war wounds) an attempt at repair of the main artery by end-to-end suture, or, if necessary, an attempt to apply a venous graft

between the separated ends should be made, provided this in itself did not add an extra hazard from hemorrhage by the giving way of the repaired artery, the suture line, or the venous graft.

With this in view, experiments were done in which end-to-end sutures of carotid arteries in dogs were carried out and the wound deliberately infected with dirt from the floor of the laboratory. In others a segment of carotid artery was excised and this was replaced with a venous graft by the technique described in earlier publications.[3] At the completion of the operation, and on some occasions before the graft was applied, the wound was deliberately infected with dirt from the floor of the laboratory and the wounds in all cases were left widely open. In the course of a few days all these wounds in both cases were suppurating and discharging large quantities of pus. There was edema of surrounding tissue. It was recognized that these surgical wounds without extensive contusion and laceration of soft tissues were not comparable to the torn and contused, lacerated wounds of bullet and shellfire and for that reason, together with the fact that repair in dogs is better and more rapidly effective than in human beings, the conditions of warfare were not accurately reproduced.

In these experiments, we observed that the repaired vessel in an end-to-end suture showed no evidence of necrosis and did not separate or blow out, and when heparin was given the vessel remained patent and circulation was carried on normally. Within a few days the surface of the vessel was granulating and within a short time the vessel together with the whole surface of the wound was a healing surface. These wounds finally healed by granulating without secondary hemorrhage.

Where venous grafts were applied, again the ends of the arteries used in the repair together with the venous graft showed a healthy appearance. Within a few days all surfaces of these vessels were granulating and eventually the whole wound had granulated and healed. In none of these did the graft show necrosis, giving way, or other evidence of secondary hemorrhage. Heparin was given in these experiments and the vessels remained patent, circulation carrying on perfectly through the reconstructed artery.

It would appear, therefore, that following injury to the main arterial supply to the head or extremities the best prospects for saving the extremity and also for preventing major complications, such as severe infection and perhaps secondary hemorrhage, might be provided by early restoration of circulation through the main vessels. Under the difficulties existing in warfare the easiest, quickest, and perhaps safest method of accomplishing this is by the application of a tube to bridge the gap between ends of the vessel and by giving an anticoagulant such as heparin. When this involves the use of a rigid tube such as described by one of us (G. M.)[1] or by Blakemore and Lord,[2] the repair should be considered to be only of a temporary nature. The rigid tubes either should be allowed to become occluded or should be removed and replaced by a venous graft applied by suturing or an end-to-end repair of the vessel by suturing. Even in the presence of infection, end-to-end repair of arteries and venous grafts in arteries applied by suturing survived without evidence of necrosis or secondary hemorrhage.

CONCLUSIONS

1. Rigid bands applied around the site for repair of vessels may be a menace in causing necrosis of the vessel wall. In the presence of infection the tendency to secondary hemorrhage is increased.

2. Similarly, a tight ligature around any vessel causes some modification of nutrition to the vessel wall immediately proximal to the site of ligature. In medium or smaller vessels, under aseptic conditions, this has no ill effect. However, in the presence of infection this area of necrosis may be the site from which the secondary hemorrhage may occur.

3. When it is desirable to close off a major vessel like the aorta or when a smaller vessel in an infected war wound is to be occluded, it is safer to sew the vessels carefully with a single layer of fine continuous suture. Under these conditions there is no necrosis of the adjacent vessel wall and the tendency to secondary hemorrhage is greatly reduced.

4. The possibility of reducing the number of amputations from gangrene or severe sepsis following injury to major arterial trunks of the extremity might be reduced by a reconstruction of the arterial tree by end-to-end suture or venous graft.

5. Even in an infected wound the prospect of survival of a venous graft or of an end-to-end repair of an artery is excellent. The observations being based only on experimental evidence.

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STUDIES IN EXPERIMENTAL VASCULAR SURGERY

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VASCULAR surgery may be considered the most venerable of all the surgical specialties for it began with man's first attempts to staunch hemorrhage. The report by Susrutas on the use of the ligature in 1500 B.C., to tie the umbilical cord, is believed by Warren[1] to be the first reference of its kind in the literature.

By the third century the therapeutic treatment of aneurysms by ligation of the vessel proximally and distally to the sac, followed by excision of the aneurysm, had been described by Antyllus.[2]

Vascular reparative surgery has a much more recent origin. The earliest report in the literature is that of Hallowell who, in 1759, repaired successfully a stab wound in the brachial artery of a man. The circumferential portion of the vessel wound was drawn over the shank of a pin and ligated.[2] The pin was then removed from the wound and the ligature tightened (Fig. 1).

Since Hallowell's report, myriads of contributions by experimental investigators have proved adequately the feasibility of such extensive vascular surgical procedures as anastomosis, segment transplants, shunt circulation

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(Eck fistula), cross circulation, and direct transfusion. Some of these procedures are obviously of laboratory interest only, but others, such as end-to-end anastomosis or segment transplant repair of extensive injuries which might occur in the resection of a large malignancy that has invaded an important vessel, or arteriovenous aneurysms or coarctations, are of exceedingly great importance in modern clinical surgery.

Despite the seemingly obvious indications for the uses of these proved experimental procedures, very few clinical applications have been reported. There is apparently a general and widespread reluctance on the part of surgeons to attempt reparative procedures. Some of this reluctance may be due to hazy conceptions as to the optimal technique commensurate with success; some of it may be due to excessive fear of postoperative intravascular thrombosis with its possible sequelae of events; some of it may be due to the widespread belief that collateral circulation is *usually* sufficient to invalidate the need for more dramatic procedures; and finally, many surgeons may have tried various methods enthusiastically described as simple "sure fire" techniques, only to fail, and consequently are discouraged as to the relative value of all vascular surgery.

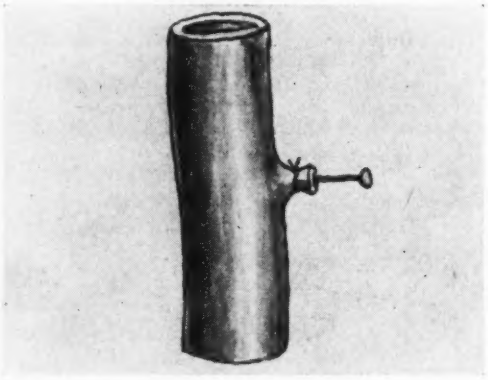

Fig. 1.—Hallowell pin method.

Because many conflicting opinions in the experimental literature do exist, and because many new factors, such as anticoagulants, have been introduced, it was decided to review the field, repeat the techniques, and, if possible, summarize the basic principles inherent in successful arterial surgery. A very short representative résumé of the history will illustrate the more common controversial points to be studied. Only those techniques which are representative of a new approach, modification, or improvement will be described.

Assmann, in 1772, repeated the technique of Hallowell in using the femoral arteries of dogs.[2] In a series of ten or more experiments all incisions became infected, resulting in purulent drainage, sloughing, and eventual failure of the suture, followed by either hemorrhage or thrombosis. Unaware of the significance of sepsis, he condemned reparative procedures on vessels as impractical, an opinion which apparently carried weight, for no further investigations were attempted for over 100 years until Gluck, in 1881, again renewed efforts to suture arteries.[2]

The first outstanding treatise on the subject was presented by Jassinowsky in 1889.[2] Twenty-two of twenty-six end-to-end anastomoses of the carotid arteries of sheep were successful. He stressed through asepsis and used fine curved needles and fine silk. The sutures were interrupted, placed 1 mm. apart, encompassed the adventitia and media, but avoided the intima.

Doubt as to the necessity of using interrupted sutures and avoiding the intima was raised by the favorable reports of Silverberg in 1897 and 1898.[2] He used the continuous over-and-over stitch, and included the intima.

The seemingly logical advantages of the mattress suture, which everts the ends of the artery and permits comparatively extensive intima-to-intima contact with a minimal exposure of suture to the blood flow, were studied by Briau and Jaboulay.[2]

Failure resulted in ten experiments on the carotid arteries of dogs, but success was obtained when the technique was applied to the carotid artery of a donkey. Here, then, were introduced two additional variables: the merits of the mattress stitch versus the simple interrupted or over-and-over suture, and the question of the minimal size of vessels commensurate with successful repair.

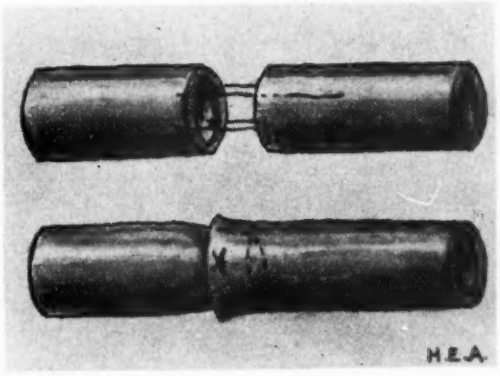

Fig. 2.—John B. Murphy mattress suture technique.

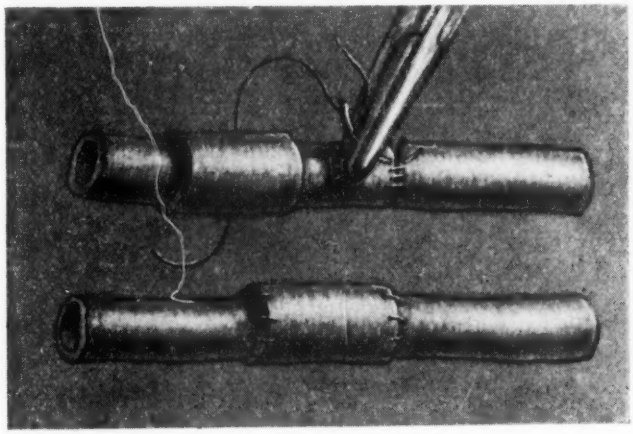

Fig. 3.—Gluck's cuff method.

In 1897, John B. Murphy reported the successful end-to-end repair of the femoral artery of man by applying the technique often used for anastomosing ureters. Two mattress sutures, 180 degrees apart, are inserted first in the central end of the artery and then passed from the inside to the outside of the walls of the distal end of the artery. Consequently, the central end is invaginated into the distal end (Fig. 2). This simple technique is not uniformly dependable.

By this time there was no doubt that anastomosis of vessels, under favorable circumstances, could be accomplished. Therefore, subsequent research was devoted to the task of simplifying the procedure.

Gluck, in 1898, introduced his "cuff" method.[2] The cuff consisted of an autogenous segment of vein telescoped over the suture line. The cuff reinforced the suture line and helped control leakage (Fig. 3).

In 1900, Payr introduced the first version of his magnesium cannula.[2] It resembled a diminutive napkin ring with two grooves. The central end of the artery is slipped through the lumen of the ring and the end cuffed back and tied to the farthest groove. The distal end of the artery is then stretched over the central end of the artery and secured by a ligature placed over the nearest groove (Fig. 4). An improved version of this ring, using a perforate disk face, was later described (Fig. 5). A recent modification of the Payr ring, with an enviable record of success experimentally and clinically, is the vitallium tube technique.[3]

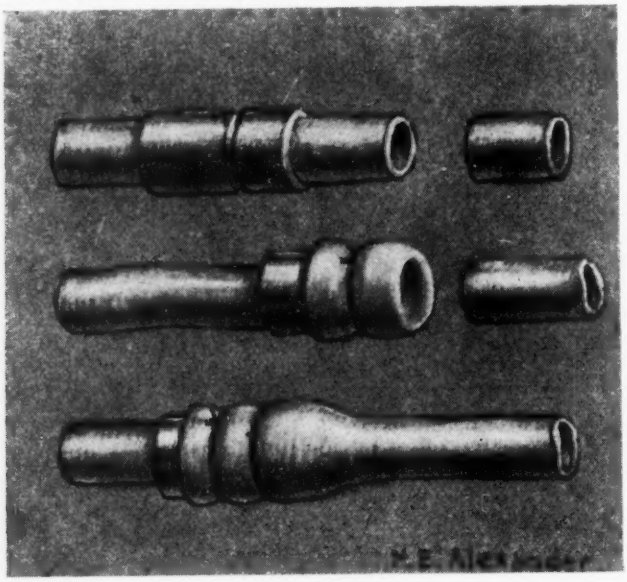

Fig. 4.—Payr ring.

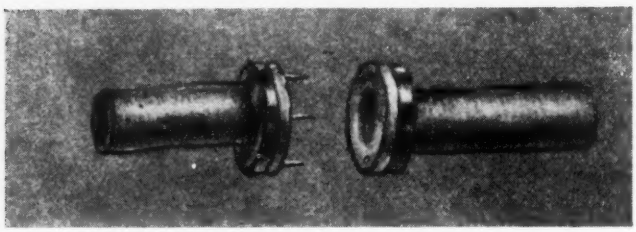

Fig. 5.—Payr's improved disk and ring.

Although by this time all of the essential principles of vascular repair had been described, it remained for Carrel and Guthrie[4] to present the most classical example of research in the field. Their many reports, working together, and later singly, described the unprecedented limits which can be attained in vascular surgery. They did long-term follow-up studies on such fascinating subjects as auto-, hetero-, devitalized tissue, and foreign body (glass and rubber tube) transplants into the arterial system. They standardized the essential procedures and introduced their three-stay suture technique which simplified and permitted the successful repair of arteries much smaller than heretofore possible. Their results set the standards to which all others are compared.

In this method the ends of the artery are united by three interrupted sutures placed equidistantly (120 degrees) apart. The assistant then grasps any consecutive two of the three stay sutures, one in each hand (Fig. 6). Mild traction everts the ends of the artery slightly so that the surgeon can sew the segment with a straight arterial needle. After one segment is sewn, the assistant rotates the stay sutures so as to advance to the next segment until each of the three segments has been sewn in turn. The continuous over-and-over stitch is used.

Although the Carrel-Guthrie technique was a decided advancement, it still required considerable skill, not only by the surgeon but by his assistant as well. Much depends upon the steadiness and degree of tension applied to the stay sutures. Also, it is exceedingly difficult to apply the principle when working in a cavity. To circumvent these criticisms, Horsley designed and introduced a mechanical aid which he called the "Arterial Suture Staff."[2] This instrument is somewhat V shaped, with one leg long and the other short. The

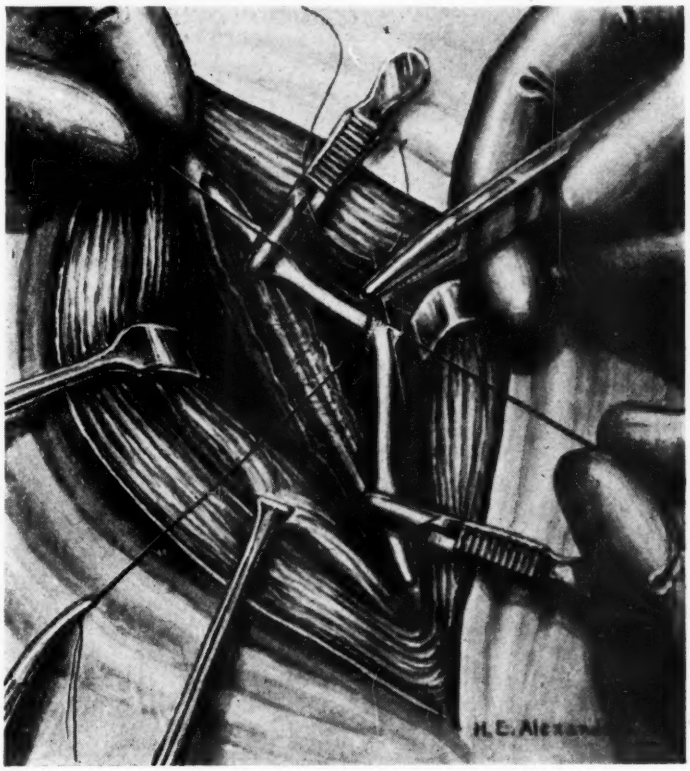

Fig. 6.—Carrell-Guthrie three-stay suture technique.

staff has projecting buttons along both shanks. The three stay sutures are fastened to the appropriate buttons, insuring constant precise tension. The trained assistant is not necessary and the staff permits work inside of deep cavities (Fig. 7).

Horsley used the so-called "cobbler" suture, which is a continuous double mattress. The thread has needles at both ends. After the first stitch is centered at one-half the length of the thread, a needle is taken in each hand and thrust through both margins of the same part of the artery, but from opposite sides (Fig. 7). The hands switch needles and the process continues.

The difficulties encountered in attempting to place three stay sutures equidistantly apart in *two* halves of a contracted and retracted distensible tube

are responsible for most of the failures in end-to-end anastomosis. If the stay sutures are not precisely placed, distortion of the two halves will result in poor approximation, leakage, and eventual failure by thrombosis.

In 1940, the soluble rod as an aid to vascular anastomosis[5] was described. In this technique the three stay sutures are eliminated entirely. The ends of the artery are stretched and approximated *accurately* over the soluble rod and sutured by one continuous over-and-over stitch. The rod rapidly dissolves in the reinstituted blood flow. The system permits operation in deep cavities of small dimensions.

Also in 1940, Murray[6] opened an entirely new field of possibilities with his description of the uses of heparin in experimental and clinical cases of vascular repair.

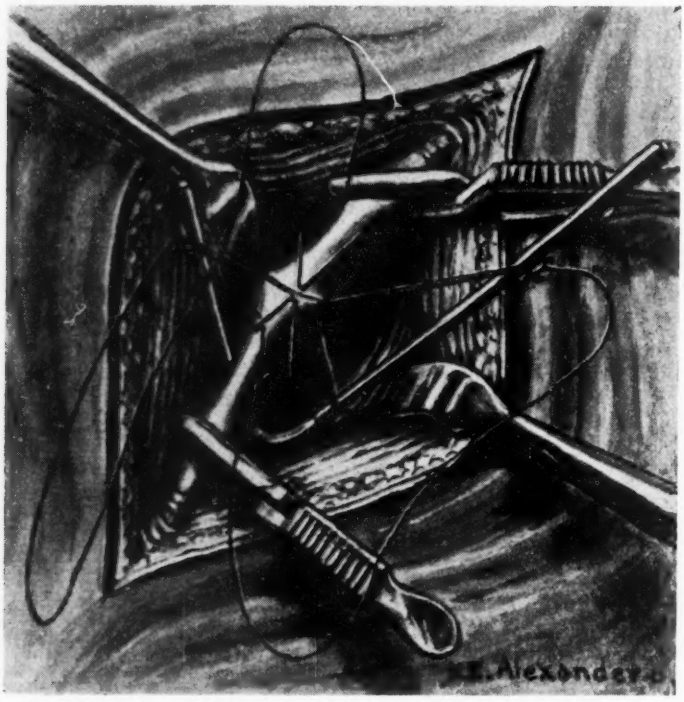

Fig. 7.—Horsley's suture staff and cobbler suture.

From this brief résumé of representative techniques we are now ready to investigate the merits of each technique and to determine and evaluate the common factors essential to success. We know that the surgical anastomosis of blood vessels is feasible and can be accomplished by many methods. What we must find out and understand are the causes and mechanism of failure.

In brief, we must consider: (1) Infection, (2) minimal size of vessel commensurate with average success, (3) coats of the vessel included in the stitch, (4) optimum spacing of the stitch, (5) optimum type of stitch, (6) evaluation of factors involved in intravascular thrombosis, (7) types of suture material, and (8) anticoagulants.

EXPERIMENTAL STUDIES

Infection.—The subject of infection is not readily adaptable to controlled research. Observations were limited to those cases in which unintentional infection had occurred. There were approximately fifteen purulent infections in over 250 experiments. Most of these fifteen were observations on techniques that were failures under ideal conditions, therefore it was impossible to evalu-

ate the significance of infection as a cause of failure. In four cases, when proved technique was used, followed by subsequent infection, three were functional and one thrombosed. In one case the infection eroded into the artery about one inch from the suture line with resulting hemorrhage and death. However, in this case the vulnerability of the artery was probably not much greater than in an unoperated artery existing under identical conditions. There is no evidence that thrombosis of an anastomosis in an infected field increases the susceptibility of the subject to a systemic bacteremia.

A thrombosed artery will often canalize after quiescence of the bacterial invasion and thus restore a favorable percentage of function. It is felt, therefore, that the existence of unfavorable conditions met with in dirty traumatic wounds should not in themselves deter attempts at restitutional surgery. Temporary function also permits development of collateral circulation which in physiologic effect often accomplishes the same end results.

Minimal Size of Vessel Commensurate With Average Success.—The absolute limitations imposed by the physical relationship between vessel size and suture size permit the successful anastomosis of arteries far smaller than any vessel in adult man which may require anastomosing. These factors will be discussed with the physics of intravascular clotting.

I was consistently successful in my efforts to anastomose the carotid arteries of dogs of 30 pounds weight. The average outside *functioning* diameter of these vessels is slightly less than ½ cm. Therefore, this size of artery was chosen arbitrarily as the control size for the comparative studies of techniques.

Standard arterial silk sutures* were used throughout. The sutures come in one size, but a choice of a straight, one-half curved, or full curved round needle may be had. All types were used.

Coats of the Vessel Included in the Stitch.—The artery or vein has three histologically distinct layers: intima, media, and adventitia. The intima lines the vessel and consists of flat endothelial cells. The initma is usually about two or more cell layers thick. It derives its nourishment from the blood flow within the vessel itself. The media is composed of smooth muscle and elastic connective tissue. It is thick in an artery and thin and weak in a vein. It derives part of its nourishment from minute penetrating capillary blood vessels which arise from a plexus of vessels termed the vasa vasorum. The vasa vasorum is contained in the outermost layer of the vessel—the adventitia. Besides the vasa vasorum the adventitia consists of loose areolar and connective tissue.

The main difficulty encountered in including this layer in the suture bite is that the adventitia is "sticky" and will adhere to the suture material tenaciously. As a result it will either snag the thread, causing breakage, or it will be carried by the thread into the lumen of the vessel where it tends to promote intravascular clotting. The adventitia is weak and imparts little, if any, strength to the suture line. It can be stripped back from the suture site readily. Consequently, it is not advisable to include this layer in the suture. After the suturing is completed, however, the adventitia should be worked back to its former position. This enables the vasa vasorum to reestablish nutrient connections to the media.

The question of the inclusion of the intima in the suture is limited by practical aspects. It is exceedingly difficult, tedious, and impractical to join adequately two arterial ends by sewing through the media only. With practice and patience it can be accomplished in a very large artery. I attempted many

*Supplied by Johnson & Johnson, New Brunswick, N. J., and Chicago, Ill.

times to avoid the intima, without success, except in one case. In this artery about one-half of the intima escaped the suture. When the animal was sacrificed one month later the artery was functioning, but that part of the intima not held by the suture had retracted about 3 mm., exposing media to the stream. There was an organized mural thrombus in this area. Histologic studies indicated endotheliozation of this clot was in progress. The rest of the suture line was not only free of emboli, but was completely encapsulated in endothelium.

Final conclusions should not be drawn from one observation. However, in view of the severe technical difficulties presented by attempts to avoid the intima, plus the fact that almost all experimenters since Jassinowsky have included the intima, it appears evident that the intima may be included in the suture bite. In summary, the suture bite encompasses the media and intima, but not the adventitia.

Optimum Spacing of the Stitch.—The optimum spacing and type of suture was studied next. The first and immediate prerequisite of repair is that the leak be stopped. Jassinowsky first stressed the point that sutures placed 1 mm. apart will adequately form a leakproof repair. Moreover, the 1 mm. gap is the maximum space allowable for a leakproof repair, regardless of the type of stitch or the size of the vessel.

Although a continuous over-and-over or continuous mattress is less tiring than either the single interrupted or single mattress, nevertheless, 1 mm. spacing is a tedious procedure. Consequently, many methods have been applied to the further simplification of this problem. The most common method is the cuff technique of Gluck (Fig. 3). The cuff extends for a considerable distance beyond both sides of the suture line. Ideally the cuff should have an inside diameter slightly less than the maximum outside diameter of the functioning vessel to be repaired.

Leakage at the site of the anastomosis results in a fibrin seal of the ends of the vessel to the cuff. Application of the principle was tested, using many substances for cuffs. The arterial ends were approximated by six equispaced interrupted sutures. The following results were obtained.

In six cases using autogenous jugular vein segments, there was little or no leakage after one minute, but all vessels became thrombosed within one week. When rubber (six experiments), fascia (two experiments), peritoneum (one experiment), or viable muscle strands (four experiments) were used as cuffs, failure from thrombosis resulted in every instance. Recently a new product, absorbable cellulose, was used in two cases as a wrapping or cuff, with failure from eventual thrombosis. Four experiments were tried, using pure fibrinogen in concentrated aqueous solution held in a mold around the suture line. The fibrinogen was converted to fibrin by addition of thrombin. After allowing a few minutes for setting, the mold was removed and the blood flow resumed. The fibrin film was unable to withstand the arterial pressure.

Although the use of only six stay sutures is admittedly a radical experimental procedure, nevertheless, the failures emphasize the fact that most failures in vascular reparative surgery are due to latent intravascular thrombosis. Moreover, these embolisms present the typical gross and histologic appearance characteristic of propagating thrombi. The clot is always adherent to one part of the suture line but may have multiple points of attachment, usually at areas where the intima has retracted, exposing media or adventitia.

Some thrombus formation occurs in any suturing process, for there is always some initial oozing from the needle holes which ceases in about one

minute. But these sealing clots are within the wall where they become organized rapidly without interfering with the re-endotheliozation of the suture line.

Fig. 8 shows a typical example of the absence of mural thrombi in a successfully anastomosed artery. On the left is the segment taken three days after anastomosis. The sutures are distinct. On the right is a segment from the opposite carotid artery of the same animal taken some six weeks postoperatively. The sutures are completely covered with endothelium.

It is felt that the control of initial bleeding by a cuff creates false security. However, new possibilities in their application have been created by the use of anticoagulants, and these will be discussed under that heading.

Optimum Type of Stitch.—I was unable to obtain successful end results using the baseball stitch. Thrombosis eventually occurred. The cause for this is undetermined to date.

The Connell stitch, in my hands, could not be placed with the required precision and was quickly abandoned. Both of these methods were attempted only as part of the general research into suture techniques.

Fig. 8.—*A*, Three days postoperatively; *B*, six weeks postoperatively.

The simple continuous over-and-over is by far the easiest stitch to place and, in my hands, gave the best results. The continuous mattress and the cobbler suture are a little slower and more difficult to place neatly, but when properly executed, give dependable results. Single interrupted or interrupted mattress sutures may be used, but the process is exceedingly and unnecessarily tedious.

Two arguments are presented persistently in favor of the mattress or cobbler suture. First, the mattress affords a more secure bite which minimizes the tendency for the suture to pull through the tissue. Second, the mattress suture exposes less foreign material to the blood flow and minimizes tendencies toward intravascular clotting.

The first argument has some merit. It is quite true that the mattress suture has less tendency to cut through friable tissue as is encountered in old sclerotic arteries. Aside from this, there are no other practical advantages.

The second argument has persisted so long on a purely philosophical basis that it was decided to devise some experiments which might determine *quantitatively* the *part* the foreign body plays in intravascular clotting.

If a fine strand of silk is threaded through an artery at right angles to the blood flow, a tiny clot forms on the thread in the center of the stream which will grow slowly at first but with an ever-accelerating speed, until it occludes the lumen completely and the vessel thromboses. The clot grows from the center of the thread outward to the periphery of the vessel. However, if the same amount of a fine silk strand is placed along the longitudinal axis of the vessel so that the thread hugs or recesses into the intima, *no thrombus* will form, and in time endothelium will grow over the suture and encapsulate the thread.

If the thread is permitted slack so that it does not, in its entirety, lie uniformly adjacent to the intima, but parts of it wave idly into the blood stream, a propagating clot will again form. A propagating clot will also form, regardless of the position of the thread, if the thread is large enough to create turbulence in the blood flow.

It is evident, therefore, that the position of the foreign body with respect to the blood flow and the *size* of the material is of great significance.

I have applied both sewing techniques with success, but do not feel that the mattress suture has sufficient practical advantages to encourage its use over the much simpler and easier manipulated over-and-over stitch.

Evaluation of Factors Involved in Intravascular Thrombosis.—In the previous experiments the recording of data from comparative tests was of chief concern. However, it was desired to visualize some of the mechanisms at work.

A model circulatory system, made mainly of glass, was constructed (Fig. 9). The reservoir was attached to the glass tube by a flexible rubber hose which permitted changes in head pressure by raising or lowering the reservoir. One section had a venturi-like constriction, representing approximately a 40 per cent reduction in cross-section diameter. Three small spurs opened into this section. One spur was placed before the constriction, one in the throat, and the third one in the tube past the constriction. These spurs could either be opened to place material in the lumen of the tube, or they could be connected to gages or stand pipes to register pressure changes. Citrated dog's blood, diluted with three volumes of normal saline solution, was used to charge the system. The speed of flow was regulated by adjusting the height of the reservoir.

With the system at rest, the formed elements gravitate to the dependent parts, but as soon as motion is imported, two distinct phases of flow are observed.[7] The formed elements aggregate into a compact core to form the axial phase, while the clear fluid uniformly surrounds the core to form the peripheral phase. The axial phase moves at a much faster rate than the peripheral phase. Under uniform flow, none of the formed elements penetrate the clear zone of the peripheral phase and consequently formed elements are not *normally* in contact with the vessel wall. Essentially these observations are in agreement with those of Aschoff.[8]

If a small thread is introduced into the tube through a spur, it is apparent that it may rest entirely in the peripheral phase and none of the formed elements will strike it (Fig. 10). Moreover, if the thread is small enough to remain in the clear zone, there is little evidence of turbulence. However, if the thread, either because of its size or its extreme length, projects into the axial phase, pronounced turbulence will occur.

Another phase of intravascular clotting was observed at the same time, as follows: When the fluid entered the mouth of the venturi-like constriction there was no loss in phase characteristics. The speed of the stream increased,

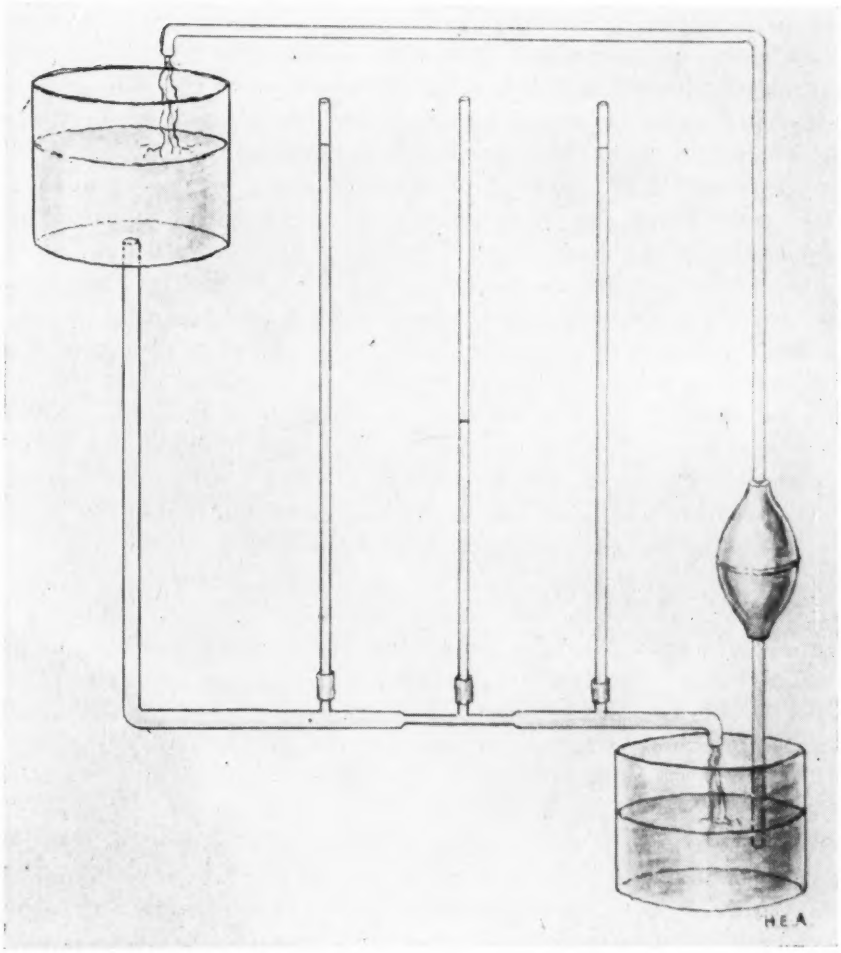

Fig. 9.—Diagram of model circulatory system.

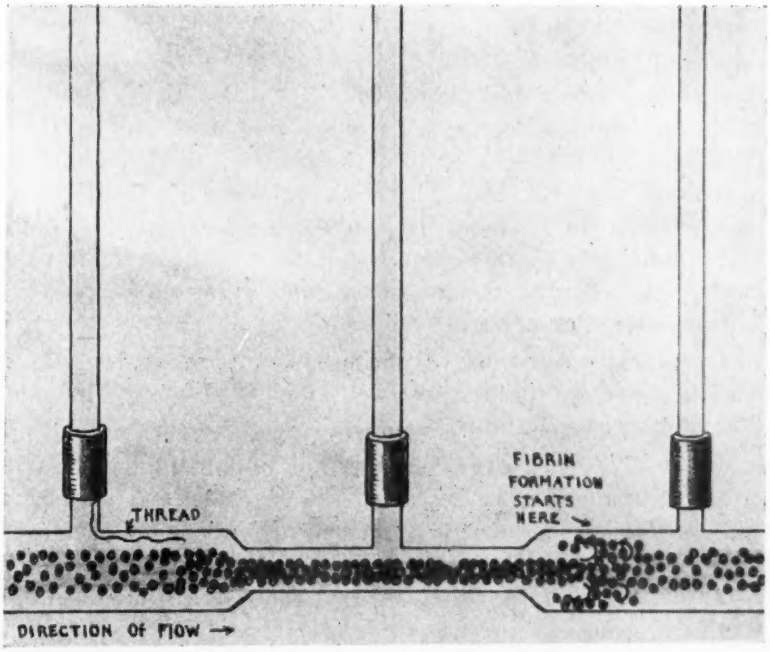

Fig. 10.—Diagrammatic illustration of two-phase blood flow and factors producing turbulence.

the clear peripheral zone was reduced in size and depth, and there was a reduction in lateral wall pressure. This is the well-known "Venturi" principle. (See any physics textbook.) When the stream emerged from the constriction there was a pronounced change which varied in intensity with the initial speed of flow. The greater the initial speed of flow, the more violent was the change. The change consisted of inversion of phase at a spot somewhat distal to the end of the constriction, the exact space varying again with the speed of flow. At this spot the axial stream struck the side walls of the tube and there was pronounced turbulence with a backward flow of cells, just as there are eddy currents behind an obstruction or a jetting stone in a fast-moving stream (Fig. 10). If small amounts of calcium chloride were added in graduated amounts to the reservoir to neutralize the citrate solution, a critical point was reached in which the blood at rest did not clot. However, prolonged agitation started the clotting chemistry. Consequently, at the point of maximum turbulence distal to the constriction it was possible to produce a very filmy propagating clot. The embolism was filmy due to the very great dilution of the blood, 3:1. This clot had a tendency to propagate against the stream.

The possibility that partial occlusion or distortion of a blood vessel could produce a propagating embolism lead to the following experiments. A single silk ligature was placed around the carotid and femoral arteries and jugular and femoral veins. The ligature occluded the diameter approximately 50 to 60 per cent.[9] Results of single partial ligation were definitely not conclusive. There was only one occluded propagating clot in an artery and one in a femoral vein. In the artery, however, the point of attachment of the clot was in the exact relative position distal to the occlusion as the propagating clot produced in the glass model. Due to the similarity of conditions imposed and the mechanism involved, the observation was of interest even though coincidence may have reduced the significance of the phenomenon. Further studies were conducted to determine the role of the intima in intravascular clotting.

A series of carotid and femoral arteries and jugular and femoral veins were crushed by clamping in an Ochsner forceps. After crushing, the injured area was teased in order to permit re-establishment of flow.

In a series of approximately ten experiments there were no occluding thrombi found one week to ten days after the initial injury. In the case of the arteries a pronounced aneurysmal bulge had occurred at the point of injury. Histologic study disclosed that the intima had regenerated and that healing, in general, was progressing by the usual means.[7] If an extensive area of the vessel, or even the intima alone, is damaged severely, then the regenerative processes cannot recoup fast enough and the vessel breaks down, resulting in thrombosis. Apparently thrombosis results from an *intensity* × *extent* formula in which both factors must be present.

The observations from these experiments help to explain the observed facts that when good approximation is obtained with fine, close suturing, no intravascular clot will form and the anastomosis will be successful.

Types of Suture Material.—The question of suture material itself was studied. No actual anastomoses of arteries were attempted with catgut. No catgut of a suitable size comparable to 000000 silk is obtainable. However, the following experiments which were performed by Potts and Smith in their joint studies on pulmonary embolism help to shed some light on this subject. The femoral vein of a series of twelve dogs was ligated. On one side silk was used and on the other side plain single 0 catgut was used. In an exploratory operation one week or ten days later, it was found that the femoral veins tied with

the catgut in all cases were thrombosed. On the other hand, there were two thrombi found in the veins occluded with the silk ligature. When the silk ligature was removed in the remaining ten, re-establishment of the venous flow continued in an uninterrupted manner. This series of experiments was interrupted by the enforced dissociation of the two surgeons by World War II and, consequently, is not complete.

A preliminary opinion, however, may be ventured to the effect that catgut ligation tends to produce thrombus formation and intravascular clotting, whereas ligation with silk does not have such marked tendencies. Apparently, catgut would not be a suitable material for arterial repair even if it existed in the necessarily small sizes.

Anticoagulants.—The excellent and extensive work by Murray[6, 10] indicates the value of anticoagulants in experimental or clinical vascular surgery. Obviously, the ability to control at will the clotting mechanism of the blood enables the operator to circumvent or ameliorate those factors which lead to postoperative thrombosis and failure.

For example, a repair executed under technical difficulties which lead to excessive intramural thrombus can be tided over the crisis by maintaining anticoagulation therapy during the essential process of organization and re-endotheliozation.

Especially is this use of inestimable value when performing venous segment transplants into arterial defects. Under the most ideal of conditions as to matching of the diameters of the venous segment and the artery, there will still be turbulence in the blood flow through the segment due to the "ballooning" of the weak, thin-walled vein. A vein segment in effect becomes an aneurysm and, as such, is subject to the identical reparative processes characteristic of the healing of aneurysms.

In brief, concentric mural fibrin deposits will tend to narrow the lumen and adventitial hyperplasia will tend to strengthen the weak media. Some fibrin deposits are desirable in that they re-establish smooth continuity of the conduit, but once this has been attained it becomes desirable to stop the clotting mechanism so that organization and endotheliozation completes the repair. By the same mechanism, the Gluck cuff has a greater opportunity for successful service.

Therefore, anticoagulants should not be considered as substitutes for surgical skill, but their value, both intrinsic and moral, must not be underestimated.

I used chlorazol fast pink[11] in my work in this field. Inasmuch as this dye is not in general favor for human use, the reader is referred to Murray's works for directions in the use of heparin.

DISCUSSION

The magnesium rings of Payr and the vitallium tubes of Blakemore and co-workers were not experimented with. I have seen satisfactory evidence of the Payr rings in use and the vitallium tubes give even greater promise of the ultimate in simplification of end-to-end and segment transplant. The rings or tubes are not adaptable to lateral or stab wound repairs as are the suture methods.

There is one point stressed by every experimenter in this field which is again repeated here for added emphasis. *Even though thrombosis may occur postoperatively, the process is a slow one which admits of the establishment of adequate collateral circulation.* Consequently, the end result physiologically is

the same as though perfect *technical* results had been obtained. To paraphrase a common paint slogan, "*Save the blood supply and you save all.*"

There are only a few technical fundamentals which must be adhered to: (1) Use fine arterial needles and silk (6 zero); (2) keep the suture gap less than 1 mm.; (3) approximate ends accurately; (4) use anticoagulants freely but judiciously; and (5) use mechanical aids when possible.

Under this heading comes the soluble rod technique. I am indebted to it for the acquisition of the technical skill necessary for the review presented in this paper. Because the soluble rod does definitely facilitate vascular surgical anastomosis, a condensed review of its preparation follows. Dextrose is heated slowly to 160° C. The slightly caramelized liquid is poured (or sucked) into sterile rubber tubes, the inside diameters of which approximate the functioning diameter of the artery to be repaired. The filled tubes are then cut into

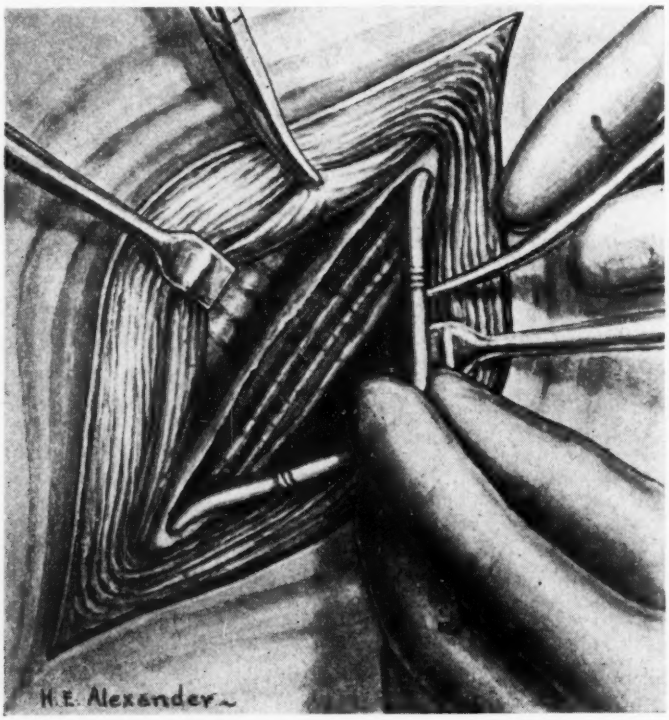

Fig. 11.

Figs. 11 to 15.—Steps in the soluble rod technique.

segments 3 cm. long. These segments are dropped into ether for a few minutes. The rubber softens and swells, permitting the dextrose rod to be slipped out of the rubber mold with ease. The rods are then coated with some substance that will serve to protect the intima from the dehydrating action of the dextrose. Paraffin, with a 50° C. melting point, makes a satisfactory coating substance which in the small amounts used (0.02 c.c.) probably presents no practical dangers from oil emboli. Recently a gelatin coat* has been experimented with. This is still in the experimental stage.

Technique of Blood Vessel Suture by Aid of Soluble Rod.—The vessel to be sutured is isolated from the surrounding tissue by packs moistened with warm physiologic solution of sodium chloride. The adventitial coat is stripped back from each end of the artery for a distance of 1 cm. The lumen is washed out with physiologic solution of sodium chloride.

*Produced by Gelatin Products Co. of Detroit, Mich.

The continuous suture technique is used. After the first suture is placed, but before it is tied, the soluble rod, corresponding in diameter to the lumen of the functioning vessel, is inserted one-half its length into one end of the artery. As the suture is being drawn tight preparatory to tying, the other end of the artery is worked over the protruding half of the soluble rod, thus approximating both halves accurately, without using stay sutures (Figs. 11 to 15).

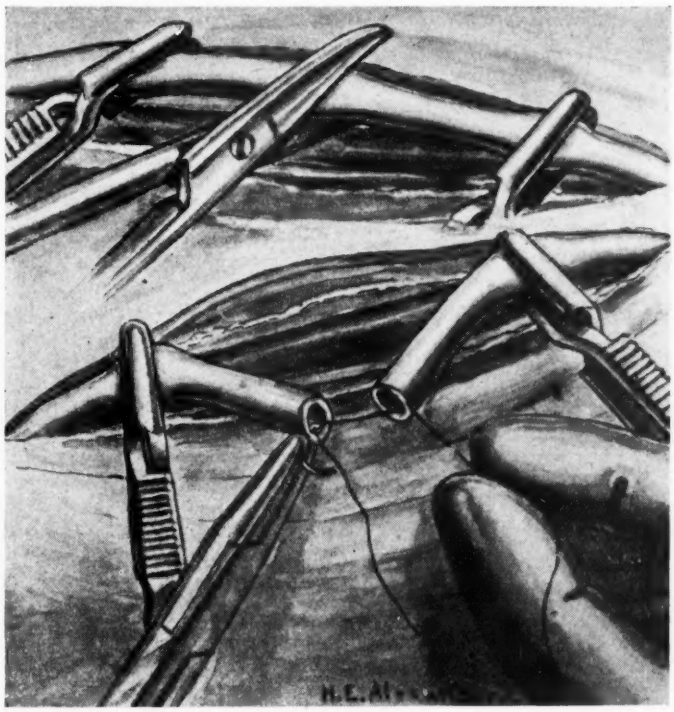

Fig. 12.

Fig. 13.

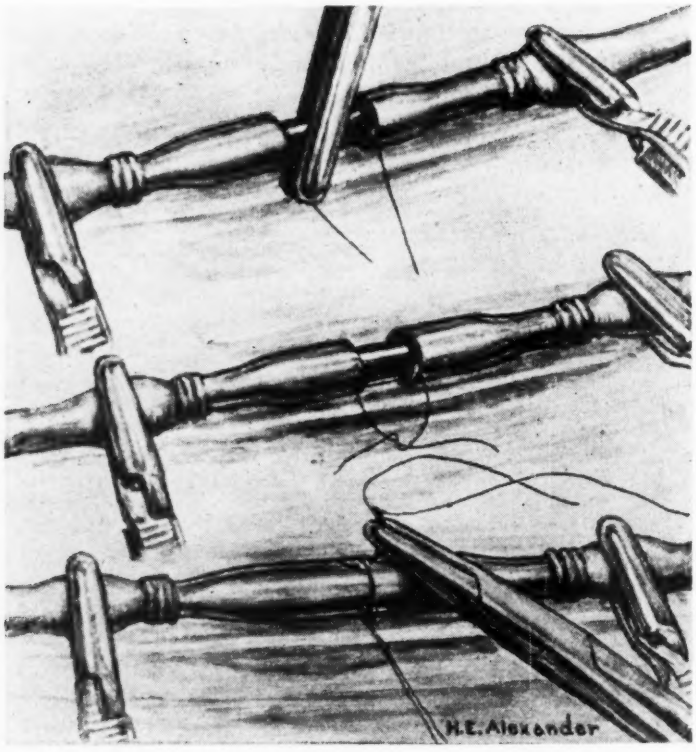

Fig. 14.

Fig. 15.

The suture is then tied. The free end of the thread is trimmed off, and the continuous over-and-over suture completes the anastomosis. Originally the straight needles were used, but the newer atraumatic half-circle round needle* has been substituted with more ease of handling. The continuous sutures are

*Supplied by Johnson & Johnson, New Brunswick, N. J., and Chicago, Ill.

placed 1 mm. apart and 1 mm. or less from the ends of the artery. Mild tension is maintained on the thread during this process in order to prevent the sutures from loosening between each sewing maneuver. The site of the anastomosis is then held lightly between the thumb and the index finger while the proximal clamp is removed. A warm saline solution pack is applied over the rod to melt the protective paraffin coating. The rod goes into solution in the pulsating blood in one minute or less. The peripheral clamp is then removed, re-establishing the circulation. Some slight oozing of blood from the suture holes and from the area between the sutures occurs immediately on release of the clamps, but this bleeding subsides within one or two minutes. After the oozing has completely stopped, permanent re-enforcement is obtained by suturing the arterial sheath securely around the artery at the site of the anastomosis.

CONCLUSIONS

It is not the province of this paper to discuss the clinical applications of the procedures described herein. It is felt that a sufficiently extensive résumé of the field has been made with experimental evidence presented in support of those procedures which can be done and those which cannot be done. It is hoped that the evidence favors predominantly the fact that anastomosis of arteries (or veins) is a feasible procedure when fundamental principles are adhered to. It would most certainly defeat the purpose of this paper if the impression were created that vascular surgical procedures are "stunts" requiring special skill. Finally, it is stressed that there is nothing to lose in attempting reparative procedures and often much to gain.

SUMMARY

1. A brief résumé of the representative techniques of blood vessel anastomosis was presented.

2. The techniques were repeated under control conditions and comparative observations made.

3. The basic principles inherent in success or failure in vascular anastomosis were studied.

4. The soluble rod technique was represented.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Colonel Willis Potts, M.C., under whose direction much of this work was originally done and for his permission to use some of our unpublished data; to Dr. A. J. Carlson and to Colonel W. Randolph Lovelace, II, M.C., and Lieutenant Colonel F. G. Hall, AC, for their helpful criticism of the recent phases of the work; to Major R. L. Clark, M.C., for his helpful suggestions based on his use of the glucose rod; to Corporal Harold Alexander for his illustrations; and to Miss Dorothy Laffel, M.T., Miss Mary Kennedy, M.T., and Mrs. Marjorie Martin, R.N., for their assistance in the experimental surgery.

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SUTURE OF THE POPLITEAL ARTERY

A Report of Three Cases

Major Pat R. Imes, Medical Corps, United States Army

INJURIES to the popliteal artery for which ligations are done are followed by a high incidence of gangrene of at least a part of the foot, usually requiring amputation below the knee. Eight consecutive patients admitted to an evacuation hospital during the early part of the Italian campaign, with injuries to the popliteal arteries for which ligations were done, met such a fate. In spite of the well-known poor results reported following vascular suture and anastomosis, we elected to try it in preference to the seemingly invariably disastrous ligation. The results of the three cases to be reported appear to have justified the change in procedure, although admittedly they constitute too few cases for the drawing of conclusions. The ultimate functional results are not known since our evacuation policy did not permit a period of observation longer than two weeks. It is believed, however, that these patients have been saved a useful extremity.

Case 1.—An American soldier was admitted May 20, 1944, with a shell fragment wound, penetrating the lateral aspect of the right knee, incurred six hours prior to admission. Examination revealed a 2 cm. penetrating wound of the lateral aspect of the right knee, with moderate hemorrhage. The popliteal region and calf were swollen and firm. The right leg and foot were cold, numb, and motionless. There was no palpable popliteal, dorsalis pedis, or posterior tibial pulse. Roentgenogram revealed a 1.5 cm. shell fragment in the medial popliteal region, just above the level of the knee joint.

Diagnosis.—The diagnosis was a severed popliteal artery, of the right leg.

Operation.—Seven hours after injury operation was carried out under ether anesthesia. A mid-thigh tourniquet was applied and posterior midline popliteal and upper calf incision was made. A large hematoma was evacuated. The popliteal artery was found lacerated below the geniculate branches, only one-fourth of its anterior wall remaining intact. A rubber-covered hemostat was applied proximal to the laceration, and the thigh tourniquet was removed. The laceration was sutured with interrupted fine silk through all layers of the vessel. The deep fascia over the upper half of the swollen calf muscles was incised. The wound was left open. A plaster cast was applied to the right lower extremity with the knee flexed to 30 degrees. A right lumbar sympathetic novocain block was done. There was no palpable right dorsalis pedis or posterior tibial pulse.

Postoperative Course.—May 21, 1944, the ankle and dorsum of the foot were warm, toes cold and blanched. There was no palpable pulse in the foot. A right lumbar sympathectomy was done. There was no apparent change in the status of circulation following sympathectomy. May 23, 1944, there was an increase in the temperature of the foot and toes, with partial return of sensation and motion. No palpable pulse was evident in the foot. May 27, 1944, improvement continued in temperature, sensation, and motion of foot. May 31, 1944, circulation to the right foot and toes appeared satisfactory, but there were no palpable pulsations in dorsalis pedis or posterior tibial arteries. Sensation and motion of foot were approximately normal. The patient was evacuated to Base Section.

Case 2.—An American soldier was admitted Oct. 20, 1944, with mine fragment wounds, perforating the left knee region and penetrating the left arm, which he had received five hours prior to admission. Examination revealed a 2 cm. wound of entrance, posterior lateral aspect of the left leg, just above the head of the fibula; the exit wound, posteromedial aspect of the left thigh, was 6 cm. above the wound of entrance. The left popliteal space

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and upper calf were swollen and firm. The left foot was cold, numb, and pulseless. Only slight motion of the foot was possible.

A 2 cm. penetrating wound was found just above the left deltoid insertion. A foreign body was palpable subcutaneously in the axilla.

Diagnosis.—The diagnosis was a severed popliteal artery.

Operation.—Six hours after injury, operation was done under endotracheal ether anesthesia. A mid-thigh tourniquet was applied and posterior midline popliteal and upper calf incision was made. A large hematoma was evacuated. The popliteal artery was found severed below the geniculate branches, with the ends retracted. The ends could be approximated by slight traction and 30 degrees flexion of the knee. The tourniquet was removed from the thigh. Thrombi were removed from both ends of the severed vessel; free bleeding was established and a rubber-covered hemostat placed on the proximal popliteal artery. An end-to-end anastomosis was done, with interrupted fine silk sutures through all layers of the vessel. The missile wounds were débrided and the foreign body removed from the left axilla; the wounds were left open. A long leg plaster cast was applied with the knee flexed 30 degrees. A left lumbar sympathetic novocain block was done. There was no palpable pulse in the foot.

Postoperative Course.—Oct. 21, 1944, the foot was still cold and pulseless, but the motion of the toes increased. Sympathetic block was repeated. Oct. 22, 1944, the foot and toes were warm. Motion of the foot and toes was free. No palpable pulse was found in the foot. Nov. 2, 1944, all toes were warm. Sensation and motion were approximately normal. There was no palpable pulse. The patient was evacuated to Base Section.

CASE 3.—A British soldier was admitted Oct. 27, 1944, with shell fragment wounds, penetrating the right side of the head, right shoulder, and right leg, incurred twenty-two hours prior to admission. Examination revealed perforating wounds of the right knee region. The wound of entrance, 3 cm. in diameter, was just above and posterior to the head of the fibula; the exit wound was 3 cm. in diameter, at the posteromedial aspect of the popliteal region at the same level as the entrance wound. The right leg and foot were cold, numb, and pulseless. There was some motion of the toes. Fluid was discovered in the right knee joint. Other wounds were of slight severity. Roentgenogram showed fracture of the lateral tibial plateau and medial femoral condyle.

Diagnosis.—The diagnosis was a severed popliteal artery and compound fractures of the right tibia and femoral condyle.

Operation.—Twenty-three hours after injury, operation was performed under endotracheal ether anesthesia. Posterior midline popliteal and upper calf incision was used. A small hematoma was evacuated from the popliteal space. The popliteal artery was found apparently contused and thrombotic 2 cm. above the bifurcation. There was no detectable pulsation distal to the injured segment. A rubber-covered clamp was placed on the artery just above the injury. The artery was incised longitudinally and the thrombus extracted; free bleeding was established. The incision was closed with fine silk interrupted sutures through all layers of the vessel. The adventitia was removed from a segment of the artery just above the injury. The popliteal vein was ligated. Other wounds were débrided. The knee joint capsule was sutured laterally, but left open posteriorly. Twenty-five thousand units of penicillin were injected into the knee joint. All wounds were left open. A long leg plaster cast was applied. A right lumbar sympathetic novocain block was done. The foot was cold and pulseless.

Postoperative Progress.—Oct. 29, 1944, the foot was cold and pulseless. Oct. 30, 1944, the foot and leg were warm. Motion was good and sensation was returning. Nov. 3, 1944, circulation to the leg and foot was apparently satisfactory, but there was no palpable pulse. Sensation and motion were approximately normal. The patient was evacuated to Base Section.

COMMENT

In our earlier experience, the patients reported in Cases 1 and 2 would have had ligation of the popliteal artery and, from our experience, this would have resulted in an amputation below the knee. That a more favorable result was obtained is attributed to establishing a sufficient circulation at least temporarily by suture of the vessel. In the event that thrombosis of the artery at the site of suture eventually occurs, the collateral circulation becomes developed sufficiently to prevent gangrene and to maintain a useful extremity.

It is impossible to evaluate accurately the importance of sympathetic block and sympathectomy in these cases. These procedures were of no avail in our earlier patients having ligations, and without striking benefit in the three cases reported. There is sufficient theoretical reason to believe that sympathetic injection has enough merit to justify its continued use.

The relative importance of thrombectomy and relief of arterial spasm by lumbar block and the periarterial sympathectomy in Case 3 is unknown, but it is believed the former was the more important factor in the result obtained.

SUMMARY

1. Ligation following injury of the popliteal artery results in a high incidence of gangrene requiring amputation.

2. Three cases, in which there was traumatic interruption of the popliteal artery and in which suture was done with apparently favorable results, are presented.

MULTIPLE ARTERIOVENOUS ANEURYSMS

Report of a Case of Four Arteriovenous Aneurysms in One Individual

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TRAUMATIC arteriovenous aneurysms, although relatively rare in civil practice, occur surprisingly often among wounded military personnel in World War II. The diagnosis is ordinarily not difficult to make. Many cases will go unrecognized for long periods of time, however, unless great care is exercised to include in the examination auscultation and palpation in the neighborhood of each wound for the presence of bruit and thrill. Nor should the examination be concluded with the finding of one arteriovenous fistula. It is not a rare occurrence for multiple fistulas to be present in a single individual. Undoubtedly the numerous small shell fragment wounds which result from high explosive shells, grenades, land mines, bazookas, etc., account for the multiplicity of vascular lesions.

Elkin* has recently called attention to this fact in reporting a patient who had three arteriovenous fistulas in the two posterior tibial vessels. I wish to present a case in which four arteriovenous aneurysms occurred in a soldier, two of them associated with a small saccular aneurysm. Diagnosis of a single arteriovenous fistula was made for the first time two and one-half months after injury and the remaining arteriovenous communications were not recognized for some time. This case is of interest not only because of the multiplicity of the arteriovenous aneurysms, but also because it serves to emphasize the necessity for extreme thoroughness in examination and operative treatment of such patients.

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*Elkin, D. C.: Arteriovenous Aneurysm; Report of an Unusual Case, Bull. U. S. Army M. Dept. (No. 84) pp. 104-106, 1945.

CASE REPORT

The patient, a 22-year-old sergeant, was admitted to Mayo General Hospital Nov. 7, 1944. Prior to Aug. 16, 1944, he had always had good health and no vascular complaints. On this date, in southern France, he was wounded by fragments from an exploding land mine, receiving multiple soft tissue injuries of both thighs, legs, feet, and of the back. At the same time he sustained a compound comminuted fracture of the right fifth metatarsal bone. There was little or no bleeding. His wounds were dressed, casts were applied to both legs, and he was transferred by ship to a station hospital in Italy. The cast was removed from the left leg September 1 and from the right November 1. He was found to have some weakness of extension of the right foot, paralysis of the right toe extensors, hyperesthesia of the dorsal surface of the right toes, and hypesthesia in the left saphenous distribution. He was returned to the Zone of the Interior and was admitted to a general hospital, October 31. Here the neurologic findings in the right foot were confirmed. The fracture was found to be healed. In addition, for the first time, it was noted that there were signs of an arteriovenous aneurysm anteriorly in the distal portion of the right leg. For this reason he was transferred to the Vascular Center at the Mayo General Hospital.

The patient had few complaints. He stated that he had some weakness of extension of the right foot and toes and occasionally a slight burning pain on the dorsal surface of the right foot. The hyperesthesia had disappeared. He had a little residual hypesthesia along the left internal malleolus. He had noted no color changes, no venous difficulties, no trophic changes, no precordial distress, dyspnea, nor cyanosis. He said that the right foot was somewhat warmer than the left and that sweating was excessive in both feet.

Examination on admission confirmed the impression of arteriovenous aneurysm in the region of the right anterior tibial vessels. A subsequent more careful examination led to the impression that he had two other arteriovenous communications. The vascular examination revealed that there was slight cyanosis of the toes of both feet in dependency. The peripheral arteries were not tortuous or thickened. The veins of the right foot were somewhat better filled than those of the left, and venous filling time was five seconds in the right foot, fifteen seconds in the left. There were no dilated or thrombosed veins. Sweating of both feet was moderate and slight pitting edema was present in the right foot and leg. There were no trophic changes. No neurologic changes were noted except for a small area of hypesthesia over the left internal malleolus, loss of extensor power in the right toes, and some weakness of extension and of eversion of the right foot. About 10 cm. above the right internal malleolus between the tibia and fibula anteriorly there was an abnormal pulsation and a continuous thrill and bruit. The bruit was audible down into the foot and up to the knee. Direct pressure over the anterior tibial vessels in this area obliterated the thrill, pulsation, and bruit, and caused a drop in pulse rate from 72 to 67 per minute. With this fistula occluded, however, there remained a loud continuous bruit which was audible posteriorly in the calf about 20 cm. above the malleoli. There was no thrill in this area. The bruit here could be obliterated by rather broad pressure against the calf muscles proximal to the point of maximal bruit. About 20 cm. above the malleoli on the posterior mesial aspect of the left leg a continuous thrill could be felt and a continuous bruit was heard. This bruit could not be obliterated by pressure in this area but ceased when the popliteal artery was compressed. The blood pressure varied from 126/72 to 116/76. With occlusion of all pulses in both legs no change in blood pressure occurred but the pulse rate dropped from 84 to 68 per minute. Skin temperatures of the toes of the two feet were about equal. On one occasion in a room at 22° C. the temperature of the toes of both feet varied from 22 to 23 and on another occasion from 32.5 to 35.5. When reactive hyperemia was carried out with the anterior tibial aneurysm occluded there was a good flush of the toes which began in twenty-five and was complete in fifty seconds. The patient had 150 healed wounds, most of which were very small and the majority of which were scattered over both legs, feet, and thighs (Fig. 1). X-rays of both lower extremities showed numerous small metallic fragments dispersed through the soft parts (Fig. 2). When the patient returned from a brief furlough he complained of some discomfort in both calves on walking and of swelling of both ankles. Examination revealed some edema of both ankles and the circumference of the right was 2.5 cm. greater than that of the left.

It was felt that the patient had three arteriovenous aneurysms, one involving the right anterior tibial vessels and the other two probably involving the right and left posterior tibial vessels.

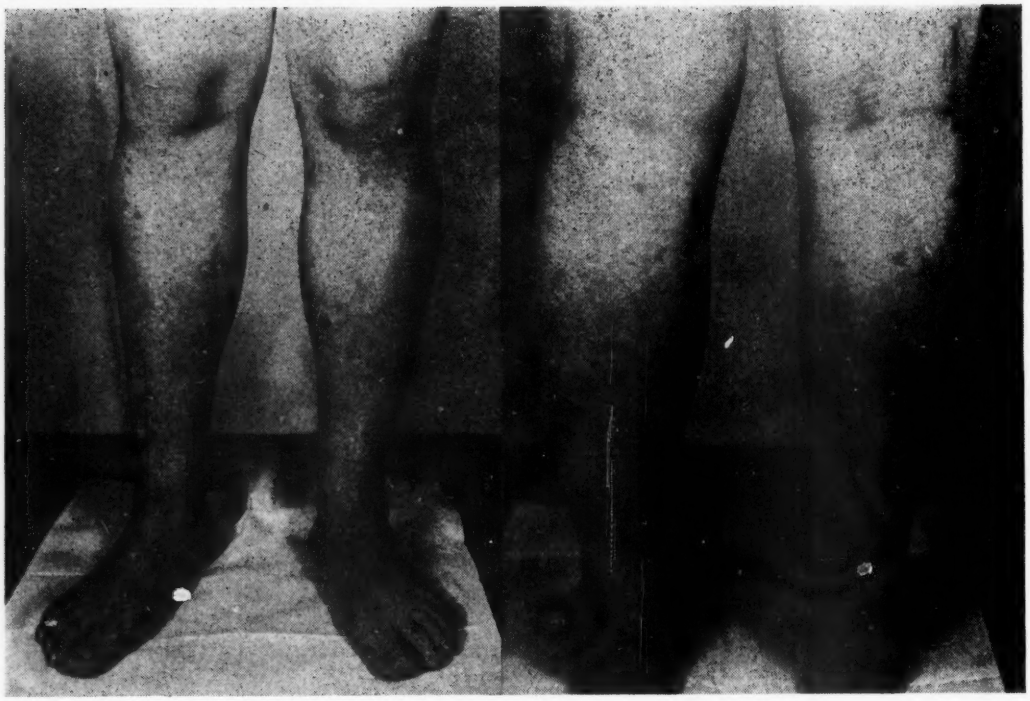

Fig. 1.—Photographs taken after completion of the operations. The numerous small wounds are shown.

Fig. 2.—Photographs of x-rays showing the many tiny metallic foreign bodies present.

On Dec. 29, 1944, the anterior tibial aneurysm was explored and a double fistula, each about 4 mm. in diameter, was found between the anterior tibial artery and two anterior tibial veins, one of which lay on either side of the artery. These vessels were resected between ligatures and the aneurysm was excised. The patient did well postoperatively, showed no evidence of vascular insufficiency, and the collateral circulation was sufficiently good so that a dorsal pedal pulse was strongly palpable in the right foot immediately after operation. On Jan. 8, 1945, an exploration was made through a posterolateral incision in the left leg. The posterior tibial and the peroneal veins were considerably dilated and communicated through two channels, while the posterior tibial vein itself communicated through a fistula about 5 mm. in diameter with the posterior tibial artery which itself exhibited a saccular aneurysm on the side of the artery opposite the communication. This saccular aneurysm was well organized and was approximately 1 cm. in diameter. The patient had no difficulty following excision and on Feb. 12, 1945, the right calf was explored for the third aneurysm. The posterior tibial artery and vein were exposed through a posteromesial incision. Both were of normal size and appearance and no thrill was present. On palpation beneath the gastrocnemius it was discovered that there was a continuous thrill on the posterior aspect of the soleus muscle somewhat mesial to the operative wound. The patient had such large

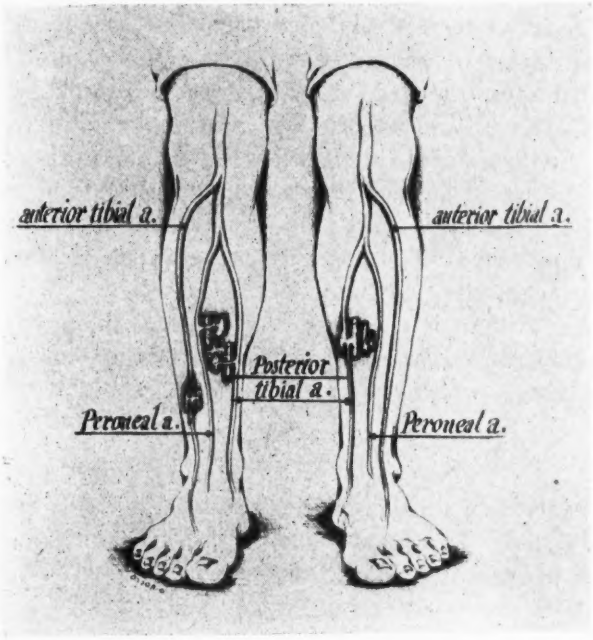

Fig. 3.—Diagrammatic sketch showing the location and general appearance of the aneurysms. No effort has been made to draw the lesions to scale. (Drawings made by T/5 A. Ossario.)

well-developed muscles that this area was not accessible through the incision and, consequently, a second longitudinal incision was made posteriorly directly over this area. The gastrocnemius was divided in the direction of its fibers and the soleus was exposed. Within the body of this muscle was found a small artery about the diameter of a matchstick which communicated with a vein about twice its size through a small saccular aneurysm 1 cm. in diameter. These vessels appeared to be muscular branches from the posterior tibial vessels. The aneurysm and the communicating vessels were excised, the artery and vein being ligated proximally and distally. The thrill and bruit in this area disappeared. Much to my surprise, however, a fairly loud continuous bruit remained somewhat lateral to and cephalad to the incision. Again this area was not accessible through the incision because of the bulk of the muscles and a third longitudinal incision was made somewhat higher along the posterolateral aspect of the calf. The fibers of the gastrocnemius were separated and the soleus was exposed. In the body of this muscle a small artery was found communicating through a fistula with a vein dilated to a diameter of almost 1 cm. This fistula was excised with a quadruple ligation of the vessels. They appeared to be muscular branches from the peroneal vessels.

Following excision of these four aneurysms the patient recovered uneventfully. He no longer had any edema and he was able to walk without discomfort. There was no significant

difference in the circumference of the two lower extremities. Both feet remained warm, although on actual measurement with a thermocouple the toes of the right foot tended to be somewhat warmer than those of the left. In a room at 23° C. the temperature of the right toes varied from 32 to 33 and those of the left from 28 to 30. Both dorsal pedal and the right posterior tibial pulses were normal, while the left posterior tibial pulse was absent. Oscillometry at the ankles was 4.5 at 90 mm. on the right side and 3.5 at 90 mm. on the left. The patient had recovered fairly normal power of extension of the right foot and had regained function of all the toe extensors save for the great toe. On walking at a fairly brisk pace for over a mile he experienced no undue fatigue in either leg. His pulse was 72 and blood pressure 108/72. There had been no reduction in cardiac size. The predicted frontal cardiac area for a man of his height and weight was 124 sq. cm. Actual measurement was 112 sq. cm. on admission and remained precisely the same on three subsequent x-ray examinations. An electrocardiogram done before the operations showed no diagnostic deformity. Since the peroneal paresis had so nearly disappeared, a neurosurgical consultant agreed that no operative procedure was indicated. The patient was returned to duty.

DISCUSSION

A case is presented which illustrates the great care which is necessary in order to avoid overlooking the presence of arteriovenous aneurysms, particularly if they are relatively small and multiple. This patient had four arteriovenous communications, the first of which was not recognized until two and one-half months after injury and the last of which was discovered only on the operating table after excision of the third. Not only should careful auscultation and palpation be an essential part of the examination of every wounded patient, but palpation for thrill and auscultation for bruit should invariably be carried out during the final stages of any operative procedure performed for the cure of arteriovenous aneurysm.

It is of interest that of the four arteriovenous aneurysms present in the patient reported, two were associated with small saccular aneurysms and a third was a double fistula in which the artery communicated directly with two companion veins.

CONCLUSION

A case is reported in which four distinct arteriovenous aneurysms occurred in a single individual. The importance of careful examination preoperatively and at the close of operation in the recognition of arteriovenous aneurysms is discussed.

SKIN TRANSPOSITION IN INCISIONAL DEFECTS

A Modification of the Z Plastic for Primary Skin Closure Following Extensive Breast Surgery

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FREQUENTLY the radical surgery of breast carcinoma requires the sacrifice of large areas of skin. When closure of the incision is attempted in these patients, the surgeon may find that he cannot bring the skin edges together and a large defect is left. This defect, although it may be in any part of the incision, is usually seen in the center. The three methods ordinarily used to cover this gap with epithelium are (1) by granulation and eventual epithelization across the defect from the bordering skin edges, (2) by skin grafting either

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immediately or after granulation has proved that spontaneous epithelization cannot occur, and (3) by the transposition of skin flaps. The standard textbooks in surgery describe fully the different methods of skin grafting and the usual methods of mobilizing and transposing skin flaps into such a defect.

I wish to report a method of skin transposition used to close extensive skin defects. This method is a modification of the Z plastic which appears in the literature and in texts on the subject; it is one which has been found very useful. Because of the almost constant presence of skin redundancy in the region of the anterior axillary line, this operation lends itself especially to breast surgery. However, it will be found useful in any situation where there is an excess of skin along the border of the incision which must be transposed before it can be utilized.

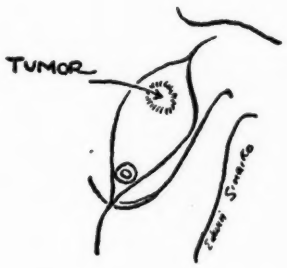

FIG I

FIG II

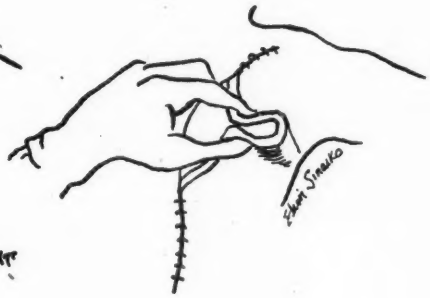

FIG III

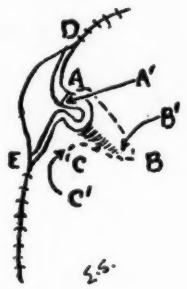

FIG IV

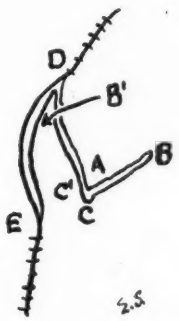

FIG V

Figs. I to V.

Following a mastectomy on the service of Dr. Max Cutler, where the patient required a wide removal of the skin overlying the tumor, it was impossible to close the skin wound in the region of the defect. This difficulty was increased because the tumor was in the upper central segment of the breast in a position where under optimum conditions there is practically no excess of skin (Fig. I). If the medial and lateral flaps were undermined, the upper and lower angles of the incision could be closed, leaving a central defect (Fig. II). This skin laxness which could be taken up in a fold at right angles to the long axis of the incision is quite a constant finding and a dependable source of skin for flap transposition (Fig. III). Judgment as to how much skin could be utilized was obtained by pinching the fold between the thumb and forefinger. All of the utilizable

skin then lay between the thumb and forefinger. The thumb and forefinger, since they were able to bring together the moderately taut skin above and below the proposed flap, also outlined the skin borders of the flap to be closed after flap transposition.

Fig. VI.—Appearance of the operative incision six weeks after surgery.

An incision was then made mobilizing the flap (Fig. IV), extending along the broken line from *A* to *B* to *C*, *C* to *E* being the pedicle of the flap. *A′* to *B′* to *C′* to *E* now outlined the limits of the skin flap itself. *B′*, the apex of the mobilized flap, was then carried to angle *D* (the upper angle of the defect) and sutured into position. Point *A* was then carried to point *C* and sutured. The transposition having been effected, appropriate sutures were placed which completed the operation (Fig. V). Fig. VI, a photograph of the patient described, shows the result of the plastic procedure six weeks after the surgery.

THE USE OF COTTON SUTURES IN LOWER ABDOMINAL SURGERY

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THE successful use of cotton thread as suture material depends on the close adherence to the principles laid down by Halstead[1] for silk. This is a very exact technique, and strict attention must be paid to place the suture carefully in order to avoid any added trauma by needless strangulation of the tissues of the wound. Cotton is an excellent suture for nontraumatic surgery, since being weaker than silk, linen, or catgut, it breaks more readily when too much pressure is applied.

The size of the suture used is of no great importance as long as the tensile strength of the thread is greater than that of the tissue approximated. Interrupted sutures are generally used,[2-11] although I[12] have had successful results sewing the layers of the abdomen with continuous threads. Nevertheless, cotton does promote a foreign body reaction, and therefore, the least possible amount of this thread should be used.

Sometimes, in order to avoid using much of this nonabsorbable material, the surgeon is negligent in tying off the small blood vessels, which very often results in the formation of a hematoma that spreads the wound open and delays healing. Careful hemostasis is essential and, in my opinion, is the most important single factor in the technique of using cotton sutures. There must be accurate reapposition of the divided structures without tension. A layer of the wound that requires a heavy suture to bring it together was not meant to be united. As Thorek and associates[10] said, "All that can be expected of a suture is that it will keep the tissues approximated. The process of healing is a natural phenomenon and occurs in spite of the suture used."

Ginkovskiy,[13] after experimenting on 100 animals and 23 human beings, advocated the use of cotton in surgical procedures on man in 1936. Following the report of Meade and Ochsner,[2] in 1939, the use of cotton as suture material has become widely applied. These authors reported that, of 196 different major operations, 191 wounds healed by primary intention. There were 3 serious and 2 minor infections, all of which healed without sinus formation. No. 30 plain cotton or "heavy duty" mercerized was used for the approximation of the peritoneum and fascia; No. 10 crochet cotton was used for retention and through-and-through sutures; No. 60 for ligation of small blood vessels and subcutaneous fat, and No. 50 black thread for the skin closure since it can be seen more easily than bloodstained white thread.

Localio and Hinton,[5] at the New York Post-Graduate Hospital, used cotton thread in more than 50 major operations and found it to be satisfactory and economical. Cotton sutures have been used routinely at the Charity Hospital of New Orleans for eighteen months in over 1,600 cases.[6] A study of 465 consecutive wounds in which cotton was used demonstrated it to be highly satisfactory. Thorek[7] followed Taylor[4] in using only one-sized cotton thread, No. 24, for every type of suture from peritoneum to skin closure.

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Nelson and Collins[8] reported on 160 gynecologic and obstetric cases in which cotton suture was used exclusively. The heaviest suture used was No. 40 in total hysterectomy, while No. 80 and 120 were used throughout in pelvic and plastic repairs. These authors pointed out that the successful use of these sutures depends on the adherence to the principles of Halstead,[1] which include such an exactness of technique that the operating time is slightly increased. In 115 cases with abdominal incisions there were no serious wound infections, and the incidence of slight infections was only 8.5 per cent as compared to approximately 20 per cent in similar cases during the preceding years. Although the patients were all ambulatory twenty-four to forty-eight hours after operation, there were no wound disruptions. The great degree of comfort was due, in my opinion, to the lack of tissue reaction to the suture material.

Pannet,[14] in making a plea for the wartime use of cotton sutures, discussed his method of suturing a laparotomy wound with removable continuous sutures. The peritoneum and posterior and anterior rectus sheaths are sutured separately with cotton threads, the ends of which are brought out of the skin and tied around a piece of rubber tubing. In eight to ten days, the ends are cut and the thread is drawn out of the wound. Hanly[15] obtained excellent results by substituting cotton and linen sutures for catgut in herniorrhaphies, and by the liberal use of sulfanilamide powder in the wound.

An interesting report is that of Sparkman and Williams[9] who, in a tent, performed 124 consecutive appendectomies on soldiers engaged in field maneuvers simulating warfare. No. 20 or/8 cotton was used for ligating the mesoappendix. The peritoneum and the layers of the McBurney incision were closed with interrupted No. 50 or 80 cotton thread; No. 100 white thread was used for ligating the blood vessels beneath the skin, and No. 80 black thread for skin closure. There were 79 appendectomies with histopathologic evidence of acute suppuration; 27 of these were gangrenous. There were 2 cases of perforation and 2 cases of contamination; these 4 were drained. Of the 120 clean cases, the incidence of wound infection was only 0.83 per cent. These results seem to justify the conclusion that cotton thread is satisfactory for field use in clean, contaminated, or infected wounds.

Thorek and co-workers[10] used cotton thread in over 400 cases, including patients with perforated appendices and diabetic gangrene, with an incidence of infection of less than 4 per cent. They reported no draining sinuses, although cotton was intentionally used in infected wounds. In their last 20 leg amputations, there were only 2 infected wounds, and in both cases catgut and silk were used.

Word and Brock[11] reported over 200 cases from Camp Shelby, in which cotton suture was used. In 22 contaminated wounds, 19 healed by primary union, with 3 wound infections and 1 draining sinus; in 198 clean cases, 195 healed by primary union with 3 infections and 2 draining sinuses. These authors stated that the success of cotton suture depends upon the strict attention to the fundamental surgical principles. They claim an increased operative time of 15 to 20 per cent and, therefore, do not advocate cotton as a good wartime suture.

Meade and Ochsner[2] found cotton thread to be an extremely satisfactory suture as it is easily sterilized, flexible, and produces little tissue reaction. Sterilization is accomplished by boiling for twenty minutes or by autoclaving for fifteen minutes at fifteen pounds pressure with the cotton wound on a rubber spool or a spool which does not expand in water, as the cotton shrinks and the fibers may be broken.

Thorek[7] said that cotton may be buried in infected wounds without inducing sinus formation, as occasionally happens when silk sutures are used. He has shown that there is no infiltration of leucocytes into cotton and consequently no formation of granulation tissue, since cotton fibers have a natural tendency to twist upon themselves, and not fray as silk or linen. This may explain the absence of draining sinuses in cotton-sutured wounds, since it is believed[2] that the infected granulations imbedded in the silk give rise to these sinuses, which are not cured until the silk thread is removed.

Wounds sewn with cotton result in rapid healing without any serum accumulation. This is termed "dry" healing by Thorek,[7] since cotton sutures produce a minimal amount of exudate, and fibroblastic proliferation appears early. The use of catgut produces "wet" healing associated with an excessive fluid exudate and delayed fibroblastic appearance. This lack of wound irritation enables the patient to have a smoother postoperative convalescence with very little wound discomfort and earlier healing. None of the reports notes the development of foreign body tumors or unusual keloid formation.

Dry cotton has less tensile strength, size for size, than catgut, silk, or linen, but it shows less decrease in tensile strength (break strength) than the others. After sutures were imbedded in tissue for ten days, cotton maintained its tensile strength at 100 per cent, whereas silk, linen, and catgut had a tensile strength loss of 25, 40, and 70 per cent, respectively.[16] For this reason the patients may be made ambulatory much sooner than in other types of abdominal closure.

The cotton chosen for suture should be limited to the smallest diameter that has greater tensile strength than the tissue in which it is used.[17] Wet cotton has greater initial strength than dry cotton, and many surgeons prefer to sterilize the thread by boiling rather than by autoclaving, since cotton has been shown[5] to diminish in tensile strength after autoclaving and to increase after boiling. However, this decrease can be abolished by rewetting the cotton before use. Mercerized cotton is much stronger than plain cotton and may be used to coaptate tissues under tension. All sutures, although cotton has a high coefficient of friction and is not likely to slip after the first throw of a square knot, should be tied with a triple throw knot and then cut on the knot.[18]

At the Manatí Municipal Hospital an experiment was begun in December, 1942, using buried continuous cotton sutures in all the layers of the abdominal wall except in hernia repair, where interrupted sutures were used. This method of suturing was first used in small midline incisions for post-partum sterilizations, and since the results were excellent, the same technique was applied to other types of abdominal closure. One hundred fifty-one lower abdominal operations were done: 87 midline incisions divided into 43 laparotomy and 44 post-partum (the latter incision is only two inches long as compared with the usual midline wound of four to six inches), 10 McBurney, 38 right rectus, and 16 inguinal. Two of the midline incisions were for cesarean section; the uteri were closed with catgut, but the peritoneum and layers of the abdominal wall were sutured with cotton.

There was 1 postoperative hernia following a post-partum midline incision. This woman had a remarkably relaxed abdominal wall with diastasis recti at the time of operation. Subsequently, she not only developed an incisional hernia, but a separation of the fascia in the midline from above the umbilicus to the symphysis pubis. This extensive ventral hernia was repaired successfully ten months later using only interrupted cotton sutures in the fascia, after closing the peritoneum with a continuous suture. At this time we obtained a sample of tissue (Fig. 1). There was dense fibrosis in the operative field and no vestige

of cotton fibers. Also, there was 1 case of a small incisional hernia in a right rectus wound in a man, that was repaired after ten months, using both interrupted and continuous sutures. Fig. 2 corresponds to sections of tissues removed after the first operation. There were foci of granulation tissue formation and foreign body reaction separating the cotton fibers from one another, but this may have been due to the secondary infection that developed. This case, together with a complete pathologic report of the fate of cotton in human tissue after ten months, has been reported elsewhere.[12] The man committed suicide five months after the second operation. When the operative wound was examined, no evidence of infection was encountered, healing having taken place with the formation of abundant fibrous tissue. Fig. 3 showed foreign body reaction, mild chronic inflammation, and dense fibrosis about clumps of cotton fibers.*

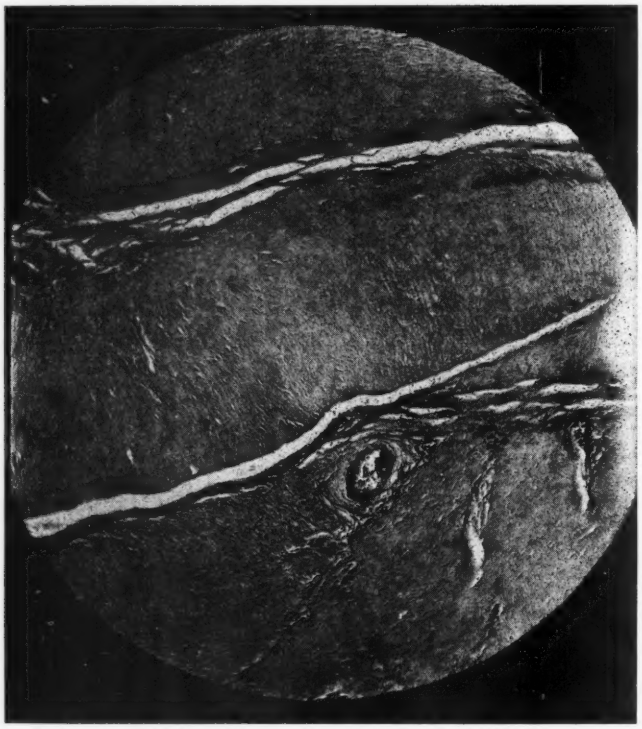

Fig. 1.—Very dense fibrosis in deeper tissues of surgical scar. (×80.)

Excepting 1 case of a McBurney incision that was converted into a right rectus wound and closed with interrupted and continuous sutures, the latter was used in this type of incision, regardless of infection, with good results. In two wounds made to drain localized appendical abscesses, drains were inserted, and after "packing" each layer with sulfathiazole-sulfanilamide powder, the incisions were approximated with continuous sutures. Although both wounds became moderately infected, they did not break down, and both healed without sinus formation in thirteen and sixteen days, respectively.

There was 1 case of sinus formation in a righ rectus incision made in a woman with acute pelvic inflammatory disease with adhesions about the pelvic organs, small intestine, and cecum to form a tumor in the right lower quadrant. This wound was closed with continuous sutures and broke down on the eighth

*The writer gratefully acknowledges the generous assistance of Dr. Enrique Koppish, Chief of the Department of Pathology, School of Tropical Medicine, San Juan, Puerto Rico, who prepared the pathologic reports and microphotographs.

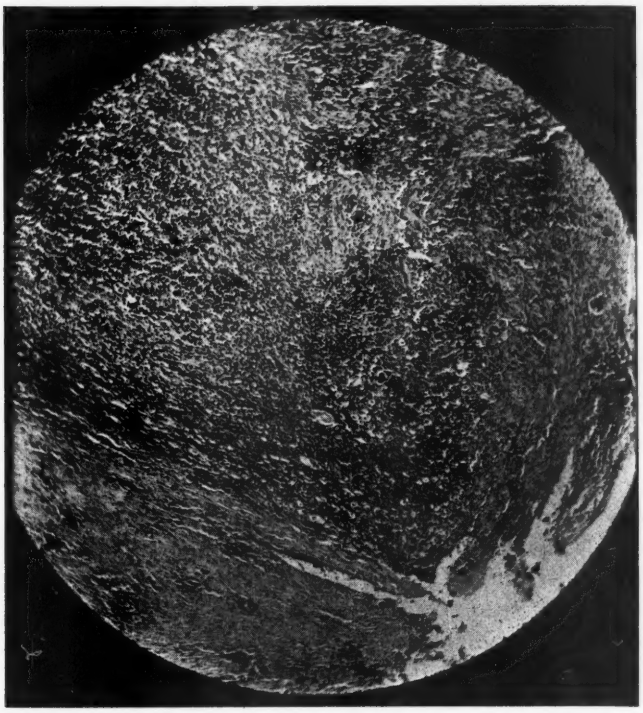

Fig. 2.—Foreign body reaction, chronic inflammation and fibrosis about cotton thread; secondary infection. ×80.)

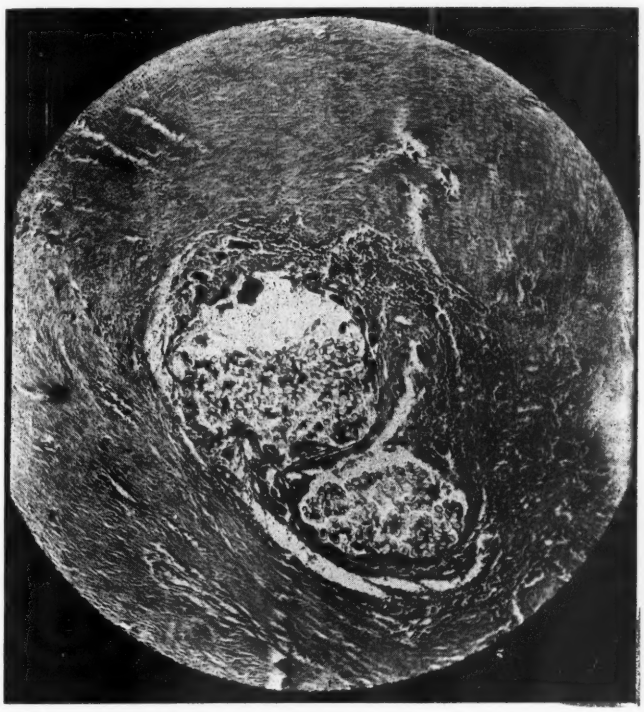

Fig. 3.—Foreign body reaction and very dense fibrosis surrounding clumps of cotton fibers. (×80.)

postoperative day despite local implantation of sulfathiazole and the taking of sulfathiazole by mouth. Healing took place in four months, only after all the cotton thread had been expelled.

In nine post-partum incisions done under 1 per cent novocain-suprarenin local anesthesia, the formation of hematomas delayed wound healing by spreading the subcutaneous tissues. Three wounds were brought together with secondary sutures, and the rest healed well by approximating the skin edges with flamed adhesive.

With the exception of the two cesarean sections which showed several small stitch abscesses, all the midline incisions healed without any infection. Two of the inguinal wounds had some drainage from small subcutaneous hematomas and slight infection of the skin edges. (The inguinal operations were all done under local anesthesia, 1 per cent novocain-suprarenin solution.) After the sutures were removed on the eighth postoperative day, both wounds healed well without any discomfort to the patient. With the exception of the herniorrhaphies the patients were allowed to sit up on the second day, but were not allowed to walk until the sutures were removed from the skin, usually by the eighth day.

After experimenting with all sizes of cotton thread mentioned in the literature, we found that one-sized cotton, No. 50, gave the best results. Where a stronger suture was needed, such as for ligating the base of the appendix, this size was doubled. Since the thread is autoclaved with the instruments and used dry, it breaks very easily if too much strength is applied to tie the first few knots, but as the thread becomes wet with the secretions of the wound, it becomes stronger. Also, it is unwise to autoclave cotton thread more than one time, if it is to be used dry, since with each sterilization the cotton becomes weaker and breaks more readily. The cost of this type of suture is so small that all unused packets are sent to the emergency room and not used in the operating room again. The cost of suturing an abdominal wound with cotton is less than 2 cents, as compared with $1.50 for catgut.

The operative technique follows that of catgut with the exception that a triple-throw square knot is used, and the suture is cut on the knot. All pelvic work and peritonealization is done with continuous sutures. The larger vessels are ligated with No. 50 thread, and unless there are any active bleeders in the subcutaneous tissues, no vessels are tied; also, the subcutaneous layer is not sutured. The superficial bleeding is usually controlled by the interrupted deep mattress sutures in closing the skin. No through-and-through sutures are used, but Taylor stated[4] that if they are used, they act as subfascial as well as subcutaneous drains, which may explain the absence of serum accumulation in the wounds of his cases. At least 5 Gm. of sulfonamide powder are sprinkled in the abdomen and layers of each wound. The skin sutures are usually removed on the seventh or eighth postoperative day.

TABLE I. SUMMARY OF CASES

	NO.	PRIMARY UNION	WOUND INFECTION	REMARKS
Clean cases	143	130	2	2 incisional hernias, 11 hematomas
Contaminated cases	8	7	5	1 sinus
Total	151	137	7	

COMMENT

From the experience in this group of cases the following principles concerning the use of cotton thread sutures may be stated.

1. Single unit, No. 50, cotton thread is used throughout the wound.

2. Continuous suture is permitted in the peritoneum as well as the fascial layers of the lower abdominal wall.

3. Transfixion sutures and figure-of-eight fascial and mattress retention sutures are not necessary.

4. The closure of the subcutaneous fatty layer is not necessary.

SUMMARY

1. Continuous cotton thread sutures have been used successfully in the peritoneal and fascial closure of lower abdominal wounds, thus speeding up the time of operative technique to equal that of catgut.

2. Single unit, No. 50, cotton thread is recommended; where stronger suture is needed, this thread is doubled.

3. Two cases of incisional hernia are reported. Nine cases of hematoma formation in post-partum midline incisions done under 1 per cent novocain-suprarenin local anesthesia were noted, emphasizing the need for meticulous hemostasis. In none of these cases did the wound disruption extend below the subcutaneous fatty layer, although one wound discharged the hematoma ten days postoperatively after the patient had been sent home.

4. The advantages of cotton thread are: low cost, easy availability; stability on exposure to heat and moisture, and ease of sterilization; a high coefficient of friction allowing the tying of secure knots, and, last, it does not irritate the wound, since it produces no tissue reaction, thus affording greater comfort to the patient.

5. The only disadvantage to the use of cotton is its lower initial tensile strength as compared with catgut, silk, or linen, but this is offset by the greater retention of tensile strength in the tissues.

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A NEW INSTRUMENT AND A SIMPLIFIED TECHNIQUE FOR THE CURE OF INGROWN NAILS

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NUMEROUS papers discussing the treatment of the relatively minor, yet common, painful condition of onychocryptosis, or ingrowing nails, are existent in the literature. It is my aim, however, to present in this paper a new instrument and a simplified technique which have proved far more effective than those presently in vogue.

It is well known that the essential pathology in this condition may vary from a simple irritation along the lateral nail fold of either great toenail to advanced cellulitis and suppuration with occasional lymphangitis. Very frequently the chronic stage is seen with granulation tissue and crusts heaped up along the nail edge. These latter cases are usually those which have been inadequately treated and have become recurrent over a protracted period of time.

Many techniques for correcting this condition have been described. These vary from palliative attempts at elevation of the offending nail edge with a small wedge of medicated cotton to a radical excision of the entire nail, nail root matrix, and paronychium as recently described by Wilson in the *Medical Journal of Australia.* Based upon the results obtained with the technique to be described, it is felt that most of these entail needless sacrifice of tissue with resultant unnecessary prolongation of postoperative convalescence.

Employing the "shark-fin" type of onychotome pictured in Fig. 1, I have devised an operative technique which is simple, brief, and completely effective in its final result. Utilizing this instrument in a series of twenty-five cases, actual operating time following anesthesia was reduced to just a few minutes. There was little or no bleeding in spite of the omission of a tourniquet and in almost every case the patient was fit for duty within twenty-four to forty-eight hours.

Two structural aspects of the nail facilitate the use of this instrument. First, the nail proximal to the lunula is membranous, and lacking in the hard, horny character of its more distal portion. This permits easy perforation of the nail from below by the point of the instrument blade. Second, the longitudinal striations make it simple to split or cleave the nail in this direction with slight distal traction on the instrument.

As for actual operative technique, following nerve block about the base of the involved toe, the instrument is employed as shown in Fig. 2. With the blade parallel to the nail, the instrument is forced proximally beneath the nail until the blade is under the eponychium (*2*). It is then rotated to the vertical and the point forced upward through the nail. As the instrument is withdrawn the nail splits evenly and cleanly (*4* and *5*). The eponychium is then freed from the segment being removed (*6*) and employing the opposite or spatula-like end of the instrument, the nail segment is freed from its bed (*7*). Finally, the blade of the instrument is employed to curette the matrix or nail-forming organ.

Postoperatively the wound is dusted with sulfanilamide powder and a small square of petrolatum gauze is applied before the dressing. Subsequent care of

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the wound consists of the application of gentian violet and dusting with sulfanilamide. In no instance was it necessary to excise a wedge of the paronychium. Removal of the irritating nail edge is soon succeeded by subsidence of the inflammatory process and prompt disappearance of crusts and granulation tissue. In a few cases this process has been expedited by the use of warm moist foot soaks for a few days following operation.

Fig. 1.—New "shark-fin" onychotome with double cutting edge blade.

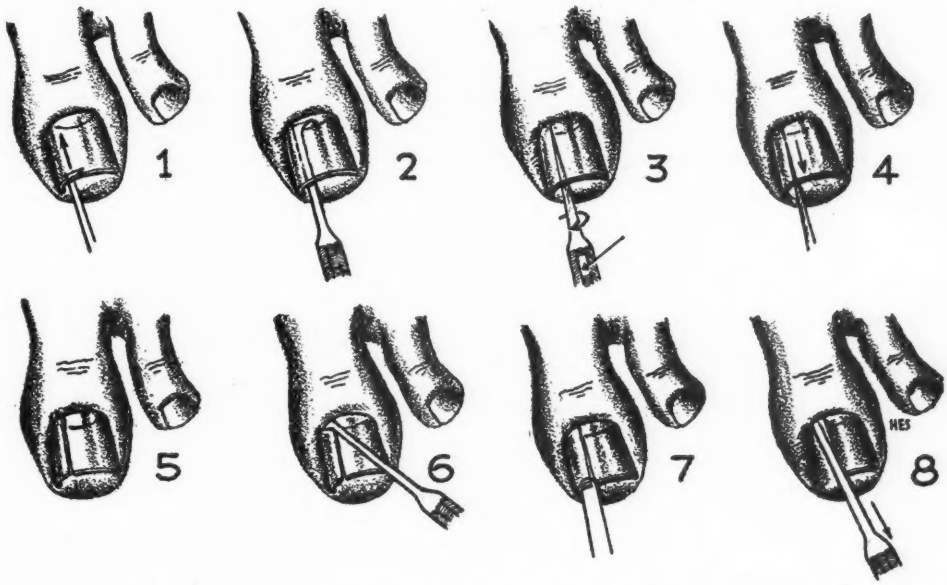

Fig. 2.—Detailed operative technique for employing new instrument. *1* and *2*, Insertion of instrument beneath nail; *3*, Rotation of blade to vertical; *4* and *5*, Withdrawal of instrument and splitting of nail; *6*, Separation of eponychium; *7*, Separation of segment being removed from nail bed; *8*, Curettage of nail matrix.

SUMMARY

A new instrument and a simplified procedure for coping with the condition of onychocryptosis have been devised and are presented herein.

With the operative technique described, conservation of tissue, minimal bleeding, and reduction of trauma have made it possible to return the patient to duty within twenty-four to forty-eight hours postoperatively.

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Book Reviews

Hypertension and Hypertensive Disease. By William Goldring, M.D. and Herbert Chasis, M.D., New York University College of Medicine. Ed. 1. Pp. 232. New York, 1944, Commonwealth Fund. $3.50.

In this book the authors accomplish what they clearly state in the preface to be their objective, "a concise presentation of our concepts of hypertension and hypertensive disease." The renal functional studies of Dr. Homer W. Smith and the clinical applications of these techniques to the hypertensive patient are well described. The sections of the book devoted to this subject and the appendices dealing with the techniques of the various procedures are in themselves extremely worth while. In addition the chapters on medical and surgical treatment, and the management of hypertension are especially to be recommended.

The 1944 Year Book of General Surgery. Edited by Evarts A. Graham, A.B., M.D., Professor of Surgery, Washington University School of Medicine, St. Louis. Pp. 736, with 271 illustrations. Chicago, 1944, The Year Book Publishers, Inc. $3.00.

This book presents a number of new operative techniques and new devices useful to the surgeon in the performance of operations or management of patients. In the main, however, the volume contains, as its editor states, very little which is strictly new. The volume contains sections on anesthesia, antisepsis, operative technique, military surgery, wound healing, tumors, and surgery in its regional anatomic aspects.

The book has come to be an important current source book for the surgeon. Many a surgeon who essays to keep abreast of developments in fields of surgery, somewhat unrelated to his own, will find in thumbing through the pages of this book, items of real interest which had not come to his notice. Moreover, most surgeons will find in it some items in their own particular field of interest which had escaped their attention on first publication.

The Year Book fulfills a useful function and should be read widely by all who profess an interest in improving their orientation in the broad field of general surgery.

Announcement

Due to conditions beyond the control of the editors and publishers, several issues of the JOURNAL are printed on an inferior grade of paper. Just as soon as the standard good grade of paper is available, its use will be resumed.